Evaluation of Reverse Osmosis Water Quality in Diwaniyah Governorate/ Iraq

Ahmed Shakir alkhair Al-Gayyim, Raid Kadhim Abed Al-asady

Department of biology, college of education, University of Al-Qadisiyah

*Corresponding author: Email:ahmedalkher35@gmail.com

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Abstract: The Canadian guideline for assessing the quality of drinking water treated by reverse osmosis (R.O.) was applied at Al- Diwaniyah Governorate/Iraq and some of its districts (Al-Hamza-Afak -Shamiya). Water samples were collected monthly from Twelve selected stations starting from August to October 2022. The physical, chemical, and microbial parameters of the reverse osmosis treated water were studied and laboratory tests for water samples were conducted. The results aligned within the Iraqi standard and the World Health Organization specification and did not exceed the permissible limit. The results of the microbial tests indicated that there was no bacterial contamination of the reverse osmosis treated water in all stations during the study period,. The results of the water quality guide (CCME WQI) for evaluating reverse osmosis water for drinking purposes indicated that the reverse osmosis-treated water was within the category (moderate- good) during the study period and for all sites.

Keywords: Diwaniyah City, CCME WQI, Reverse Osmosis Treated Water R.O.

1. Introduction

Water is an essential element for all living things and covers 71% of the Earth's area and about 65% of the components of the human body. Although water is the backbone of life, we deal with it badly, so we abuse it and contribute to its pollution with our hands, and we know perfectly well that this pollution will reach us directly or indirectly [33]. The provision of potable water has become difficult due to required to the large number of pollutants that reach it in different ways and cause many serious health problems that affect living organisms, especially humans. In our time, most water sources have been polluted, from oceans, seas and rivers to groundwater and rainwater. The daily contaminants of water that reach the human body pose a real danger to their health, whether these pollutants are biological or chemical [4]. The bottled drinking water industry is one of the most dynamic sectors of the food and beverage industry [8] despite the high cost compared to the costs of network water services.

Distribution, especially in industrial cities [19], and bottled water has become described as the fastest growing drink in the world [21] to become a competitive drink to ordinary drinking water [24], as the global consumption of bottled water since the past thirty years has witnessed a steady increase at a rate of 9% annually [8] for reasons required to consider related to consumer preference, water pollution, or as a result of problems resulting from the use of chlorine in the sterilization of drinking water [25].

The bottled drinking water industry in Iraq is very popular, and the number of its laboratories occupies 54.5% of the total laboratories of various food industries in the country and is registered with the Directorate General of Industrial Development, this industry witnesses a wide spread in light of the increasing demand for the product for reasons related to the quality and availability of drinking water [27] Which is commercialized after performing physical, chemical and biological water tests to assess its quality [29], a factor whose value is not within the permissible limit in the specifications and standards is considered the determining factor in the classification of water quality for its usability and contamination [18].

2. Material and methods

The study was conducted for some reverse osmosis water stations in Diwaniyah Governorate and some of its districts (Hamza-Afak-Shamiya), as samples were taken monthly by three replications starting from August to October 2022. The samples were collected using 1.5-liter plastic bottles. Numerous physical and chemical tests were conducted for the reverse osmosis treated water according to what was mentioned in [11] in the field the pH was measured by a pH meter, and the electrical conductivity and dissolved solids were measured by (Multi Meter device) as stated in [11]. Other measurement was performed in the laboratory, which included (total alkalinity, total hardness, calcium, magnesium and chloride measured) by the method of surfing as mentioned in [11] and measuring sodium and potassium measured by a flame photometer (Flame photometer) and nitrates measured by a spectrophotometer (UV) as reported in [11]. The bacteriological tests included calculating the total number of aerobic bacteria (ABTC) by the pour plate method using a nutrient agar as mentioned in [12]. The Water Quality Guide issued by the Canadian Cabinet for Water and Environment (CCME WQI) was followed, which is an effective model for assessing water quality and converting it to a single number ranging between (0-100) and it is characterized by flexibility in choosing the examined variables to determine the targets as well as high accuracy. To calculate the value of CCME WQI for reverse osmosis water, the study dealt with the application of 13 variables to calculate the quality of drinking water according to the Iraqi standard specifications [23].The Water Quality Index (CCME WQI) is calculated by finding three main factors and by calculating three main steps, the Water Quality Index [14] is calculated as follows

$$CCME\ WQI = 100 - \frac{\sqrt{F1^2 - F2^2 - F3^2}}{1.732}$$

(F1) Scope: represents the ratio of factors whose values do not meet the criteria set for the model.

$$\mathbf{F1} = \left[\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right] \times 100.$$

(F2) Frequency: Represents the percentage of tests whose values do not meet the established standards (failed tests).

$$\mathbf{F2} = \left[\frac{\text{Number of failed Tests}}{\text{Total Number of Tests}}\right] \times 100$$

(F3) Amplitude: Represents the amount of failed test values whose values do not match the established criteria. $\mathbf{F3} = \left[\frac{nse}{0.01\,nse + 0.01}\right]$,

$$\text{Excursion i} = \left[\frac{\textit{Failed Test Value i}}{\textit{bjective j}}\right] - 1,$$

$$\text{Excursion i} = \left[\frac{\text{Objective j}}{\text{Failed Test Value i}}\right] - 1 \quad ,$$

$$nse = \frac{\sum_{i=1}^{n} Excursion}{number\ of\ tests}$$

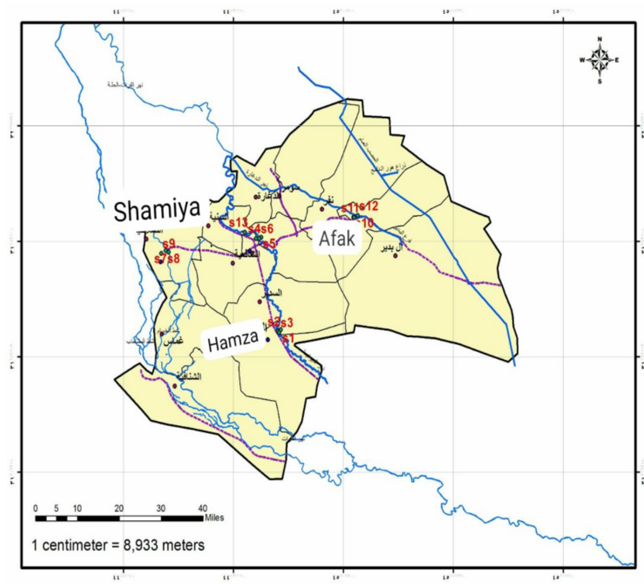

Figure 1: The study sites in Al-Diwaniyah Governorate and its districts (Al-Hamza - Al-Shamiya - Afak)**.**

Figure 2: The study location in Diwaniyah Governorate – Iraq.

The quality of water treated with reverse osmosis is determined by comparing it with

(CCME WQI) which formed of five-category [15].

The study data was statistically analyzed using SPSS version 30 to determine significant differences among coefficients. We calculated the mean ± standard deviation for the variables and computed the least significant difference (LSD) at a significance level of 1% [17].

3. Results

In the current study, the lowest pH value of reverse osmosis water was (6.20) at Station 7 in October and the highest value of (7.98) at Station 6 in August 2022 (Figure 2), while the values of T.D.S ranged between the lowest value of (12.4) mg/L at Station 5 in September and the highest value (345) mg/L at Station 12 in October 2022 (Figure 3). The values of electrical conductivity were recorded, the lowest value was (19.2) microsiemens at station 5 in September and the highest value was (518) microsiemens at station 12 in October of the same year, Figure (4).While the lowest total alkalinity value was (10) mg $CaCO_3$/L at a station of 11,8,6,4 in August 2022 and the highest value of (46) mg $CaCO_3$/L at Station 3 in September of the same year, Figure (5). As for the total hardness, the lowest value of (18) mg $CaCO_3$/L was recorded at Station 8 in August 2022 and the highest value of (200) mg $CaCO_3$/L at Station 1 in September of the same year (Figure 6).

The lowest calcium value (0 mg/L) was recorded at Station 7 in October and the highest value was (19.4) mg/L at Station 12 in September 2022, Figure (7). The values of magnesium ranged from the lowest value of (2.90) mg/L at Station 8 in August to the highest value of (44.89) mg/L at Station 1 in September 2022, (Figure 8). The study recorded the lowest chloride value of (12.68) mg/L at Station 6 in August and the highest value was (83.49) mg/L at Station 1 in September 2022. (Figure 9). As for Nitrates, the lowest value was (0 mg/L) at (11,8,7,6,4,2) station in August 2022 and the highest value of (2.917) mg/L at Station 3 in October of the same year, Figure (10).The lowest sodium value of (4.0) mg/L was recorded in the current study in Station 7 in August and the highest value of (43.78) mg/L at Station 1 in September 2022, Figure (11). While the potassium values ranged from the lowest value recorded (0.1) mg/L at stations 7,11 in August and station 7 in October 2022 to the highest value of (4.7) in station 1 in September of the same year, Figure (12). As for the microbial results, the study did not record any bacterial contamination in the reverse osmosis treated water plants throughout the study period, As shown by the results of the CCME WQI (CCME WQI) for drinking water according to Iraqi specifications, the quality of water treated with reverse osmosis was recorded between (61.08–92.57) and falls within the category (marginal-good) for the study months [15] Figure (1).

4. Discussion

The current study showed that the pH values were close at the study sites and for the three months. Thus, the values for the water treated with reverse osmosis were within the permissible limits of the Iraqi specification, except for plant 7 after treatment in October 2022, recorded values less than the permissible limit of the Iraqi specification (Figure 2), and this decrease in pH may be explained to the process of occurrence of salts withdrawn by membranes, which leads to an imbalance in the pH, The pH values of this study were close to those of Razouki (26). The results of the statistical analysis showed significant differences between the pH results of reverse osmosis treated water as well as the association of pH with physical and chemical properties. The results of the study also showed the electrical conductivity values of reverse osmosis water were less than what was mentioned in the Iraqi standard, and this decrease in the conductivity values may be explained by the fact that the treatment of water by reverse osmosis leads to a decrease in its concentrations in the water through the oxidation of positively and negatively charged salt ions (34). The electrical conductivity results of this study were higher than those recorded in the study of [26] The results of the statistical analysis showed that there were significant differences in the results of the electrical conductivity of reverse osmosis water between the stations, as well as the correlation of electrical conductivity with physical and chemical properties. The study showed that the values of dissolved solid salts in reverse osmosis water were within the permissible limit of the Iraqi standard specification for drinking water (>300 mg/l) , and the results of the statistical analysis showed that there are significant differences between the results in dissolved solid salts of reverse osmosis water between the stations, and this difference may be due to the efficiency and quality of the desalting process followed in reverse osmosis plants as well as reasons related to the nature and geology of the earth and its containment of salts that embrace the water source [35].

The results of the study indicate that the total alkallinity was less than the normal range of the Iraqi specification, and this may be attributed to the high temperatures that precipitate bicarbonates, which in turn reduce the alkalinity values [22]. The results of the statistical analysis showed that there were significant differences in the results of the total alkalinity of reverse osmosis water between the stations in August and October, while the significant differences between the stations in September were absent, There is a correlation between total alkalinity and the physical and chemical properties of different Iraqi waters, which are characterized by their low alkaline content due to the abundant presence of carbonates and bicarbonates

[10] and this is reflected in the treated water by reverse osmosis as a source of this water. The results of the study showed that the total hardness of reverse osmosis water was within the permissible limits of the Iraqi specification for drinking water, and the results of the alkalinity were similar to the results of the study [6].The hardness of water has a major role in nervous system disorders, and in areas where water contains large amounts of calcium and magnesium it has been found to be associated with higher neurodegenerative diseases as an association between the amount of these elements and the incidence of diseases was obtained from a series of Wilcoxon tests [28].The results also showed that there are significant differences between the hardness results of reverse osmosis water and the explanation of this variation may be attributed to the geological structure and the type of salts present in the soil which includes the source of water used for reverse osmosis water [16]. As well as the concentration of industrial and domestic pollutants released to the water used as a source of reverse osmosis water [20].The results of the current study showed that the calcium in reverse osmosis water did not exceed the permissible limit of the Iraqi standard and low values were recorded in some stations, and station 7 was completely absent from calcium in October 2022, Figure (7). The reason for the decrease in the amount of calcium in the water after reverse osmosis treatment may be attributed to the quality and efficiency of the treatment process and the desalting used in reverse osmosis plants, Also, insufficient amounts of calcium or low water may cause osteoporosis in humans and affect their health (American Institute of Health) [36],because of its importance in the processes of bone and dental formation, blood clotting, and the functioning of the nervous system [2].The results of the calcium of this study coincided with the results of the study [7],and the results of the statistical analysis showed that there were no significant differences between the results of calcium for reverse osmosis water in August and September and the presence of significant differences for reverse osmosis water in October between the stations, and the existence of a correlation between calcium with physical and chemical properties during the study period for the three months.

While the results of the study showed that the magnesium values of reverse osmosis water have exceeded the permissible limit of the Iraqi standard and the magnesium values were less than the calcium values in the study may be attributed to the chemical properties of the soil and geographical data of the source of water used for reverse osmosis water and therefore obtaining an adequate level of magnesium is of great importance in the prevention of oxidative stress disease and aging [13].The magnesium results of this study were consistent with the results of the study [6].The results of the statistical analysis showed that there were significant differences in the results of magnesium for reverse osmosis water between the stations and there were no significant differences in the months of September and October, and there was also a correlation between magnesium with physical and chemical properties in the three months of the study.

The results of chloride for reverse osmosis water in the current study showed that it was within the normal range of the Iraqi standard and did not exceed the permissible limit, and the results were similar to the results of other studies [26,6] While the results of nitrates for reverse osmosis water were within the permissible limits of the Iraqi specification for drinking water,

There were significant differences in the nitrate value of reverse osmosis water between the stations in August and September, and there were no significant differences in October, except for Station 3, and this difference may be attributed to climatic conditions, water continuity and the duration of its survival [5].as the source of reverse osmosis water. Nitrates have a major role in polluting and damaging water, and they are dangerous and toxic ions because of their impact on human health, as scientists and doctors have agreed on their toxic effectiveness for humans and animals and cause many cancers and children's cyanosis [30].

The nitrate results of this study were consistent with the results of the study [9] . Nitrates were also correlated with physical and chemical properties in the study. The results of the current study recorded that the sodium values of reverse osmosis water were below the limits recommended by the US Environmental Protection Agency (20 mg/L) [9]. Studies have also shown that sodium is important in regulating the osmotic pressure of the body's cells and works to balance acidity and alkalinity and maintain this balance and helps in muscle contraction [11]. It has also been shown that human cardiovascular disease and high blood pressure are associated with high sodium concentrations [3].The results of the statistical analysis showed that there were significant differences in the results of sodium for reverse osmosis water between the stations in the three months of the study and a correlation between sodium and physical and chemical properties

The study showed that the potassium content of reverse osmosis water was very low and this decrease has a negative impact and may cause health problems and risk to people with diabetes, high blood pressure, heart disease and kidney disease through the treatment of water containing potassium chloride, where potassium ions, magnesium and calcium are exchanged and thus have a negative impact on them [31], and the potassium results of this study were consistent with the study [7]. The results of the statistical analysis showed that there were significant differences between the results of potassium for reverse osmosis water between the stations in the study period and the existence of a correlation between potassium and physical and chemical properties. While the current study did not record any bacterial contamination in the reverse osmosis water of the stations examined throughout the study period, and it was within the Iraqi specifications for drinking water and did not exceed the permissible limits, and the lack of this pollution and the quality of the water and its clearance from bacteria may be attributed to sterilization processes, as ozone has high efficiency in the sterilization process and the elimination of bacteria [1] and the results of this study coincided with the results of the study [1,32]. As for the results of the statistical analysis, no significant differences were recorded for reverse osmosis water in all stations during the study period.

The results of the current study also showed the water quality guide for drinking purposes (CCME WQI) for reverse osmosis water that it falls into the two categories (marginal-good) for drinking purposes Figure (1), it is clear from the results of the study that the water quality guide for drinking purposes was an indicator that all the water that was consumed during the study was directly drinkable and this may be attributed to the fact that the values of physical, chemical, and microbial factors were within the normal range of the permissible limits, except for some factors (pH, calcium, and nitrates) that recorded a decrease slightly below the normal limit. There were also significant differences between the water stations at the selected sites and throughout the study.

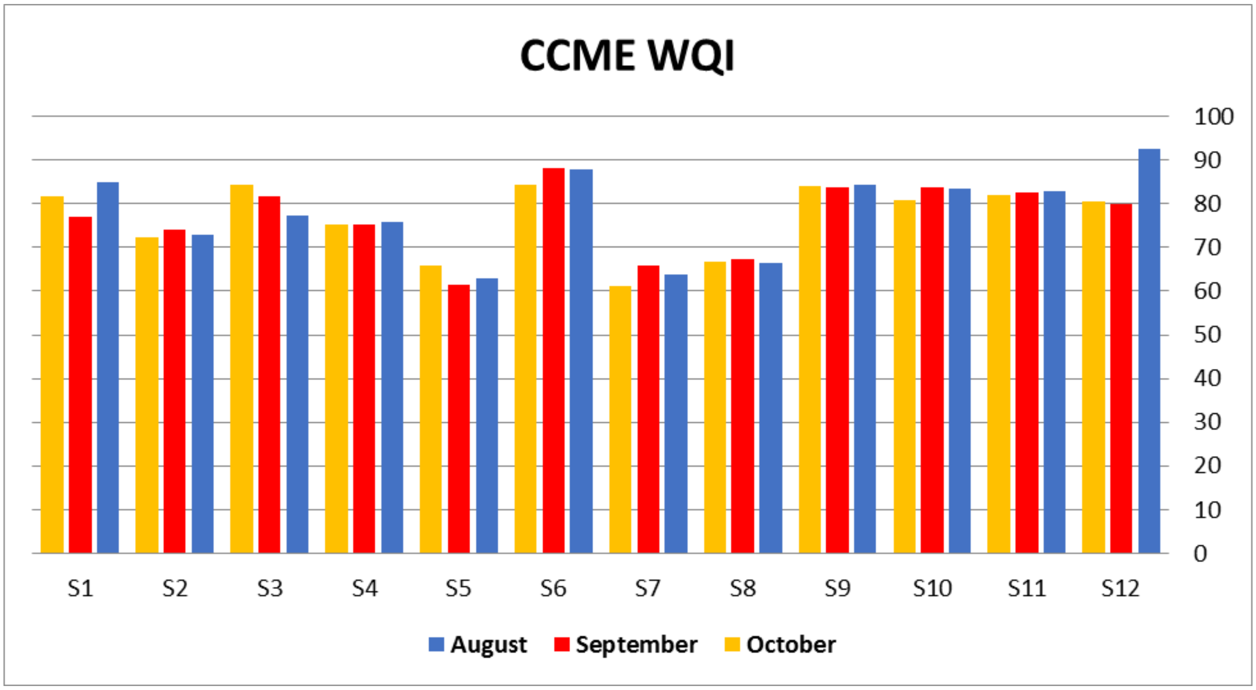

Figure (1) Canadian Water Quality Guide (CCME WQI) for. Reverse Osmosis (R.O) Water Plants

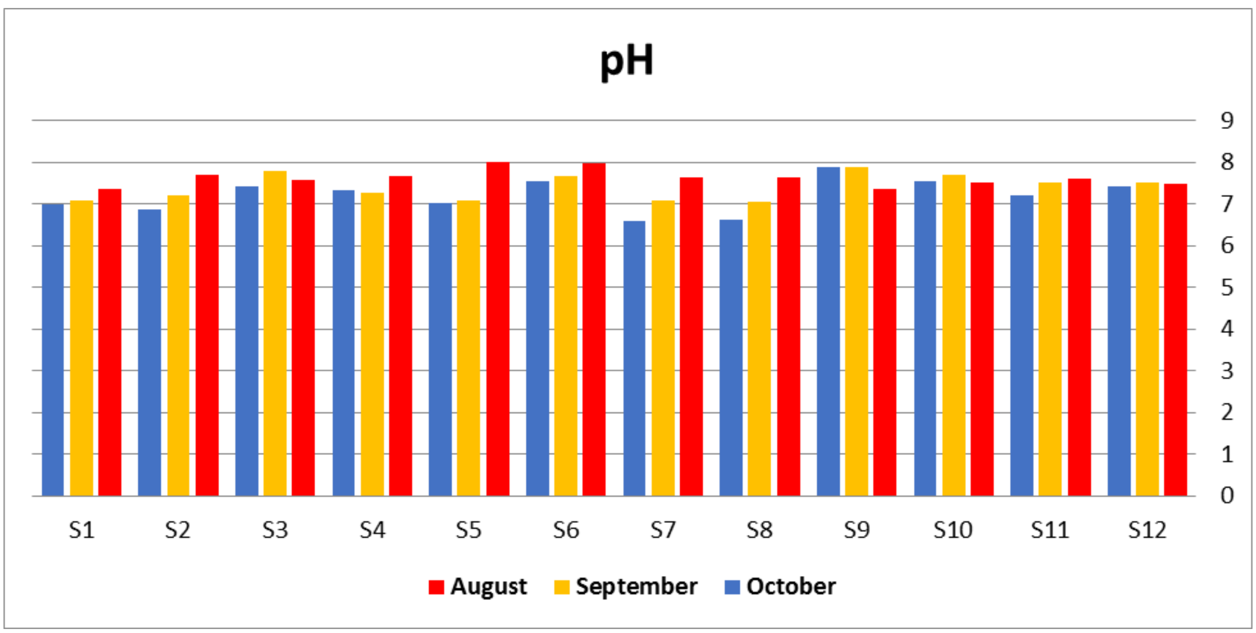

Figure (2): pH Values for Study Sites.

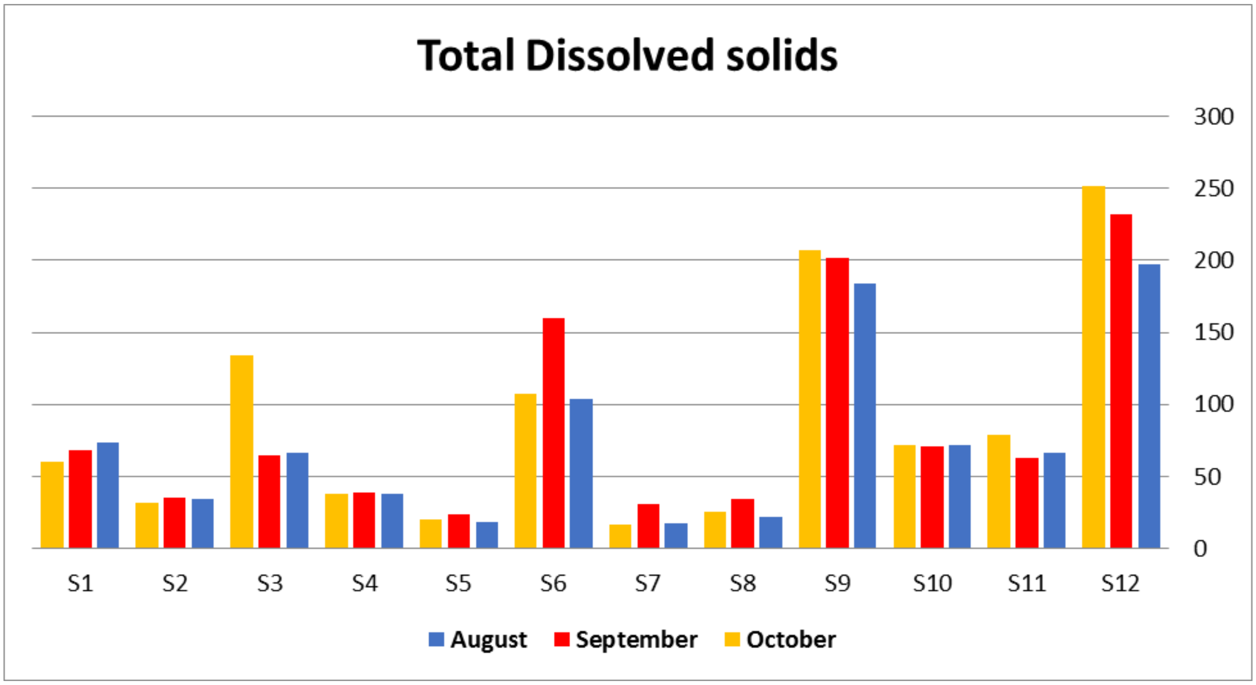

Figure (3): T.D.S Values for Study Sites

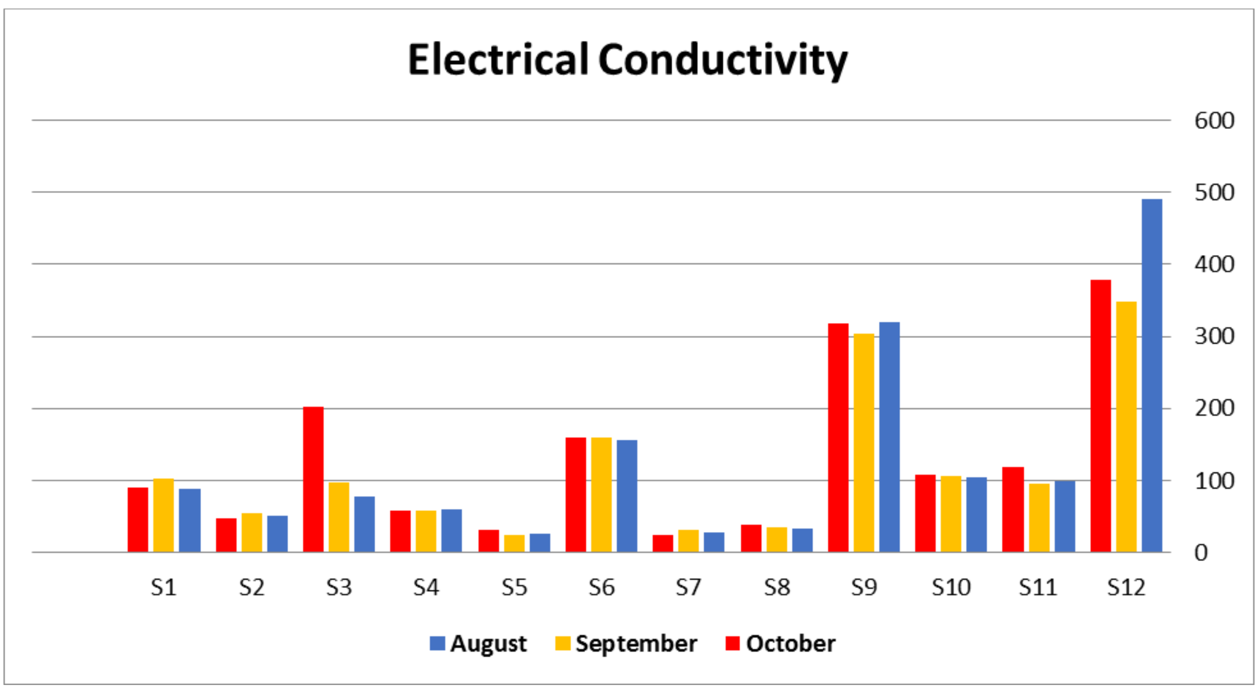

Figure (4): Electrical Conductivity Values for Study Sites

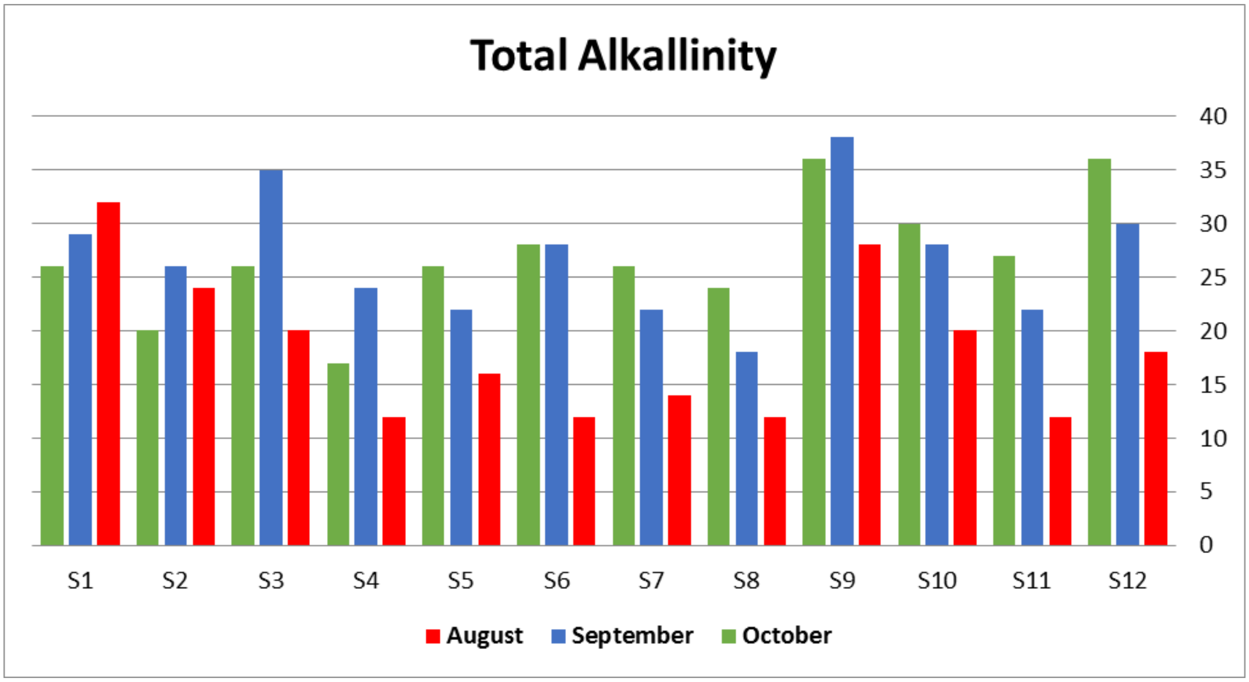

Figure (5): Total Alkalinity Rates for Study Sites

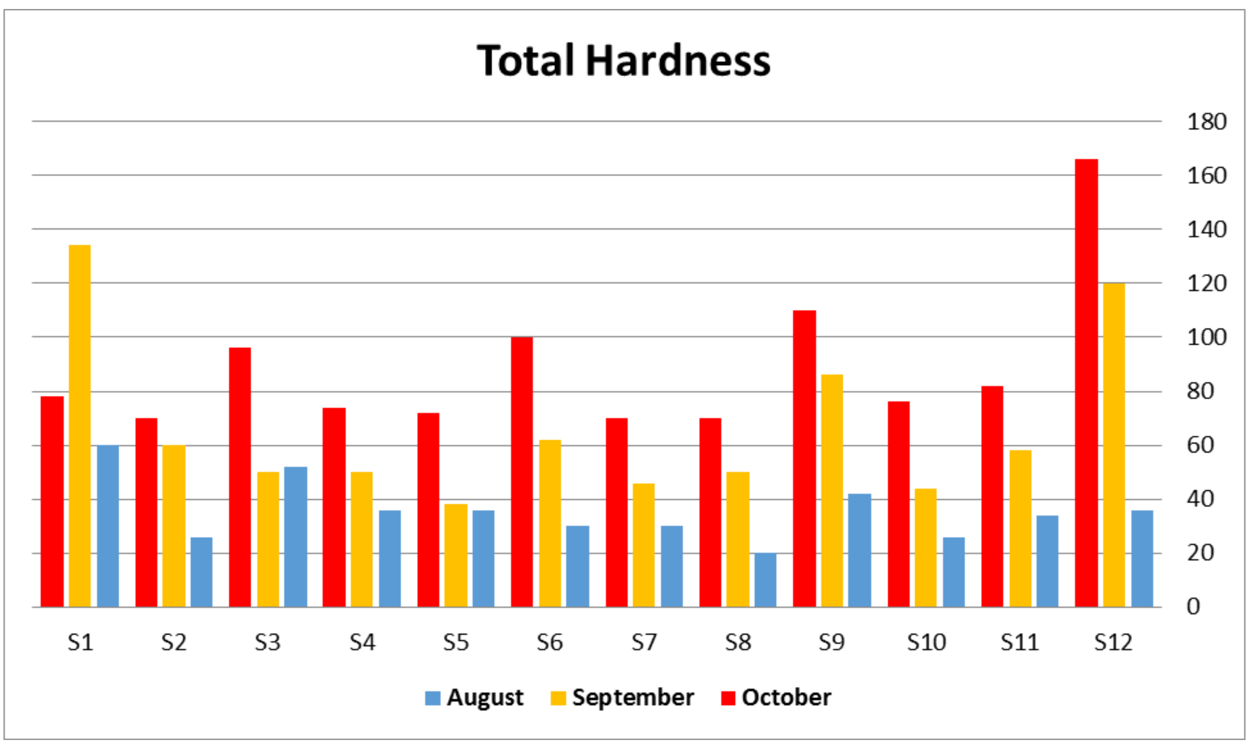

Figure (6): Total Hardness Rates for Study Sites

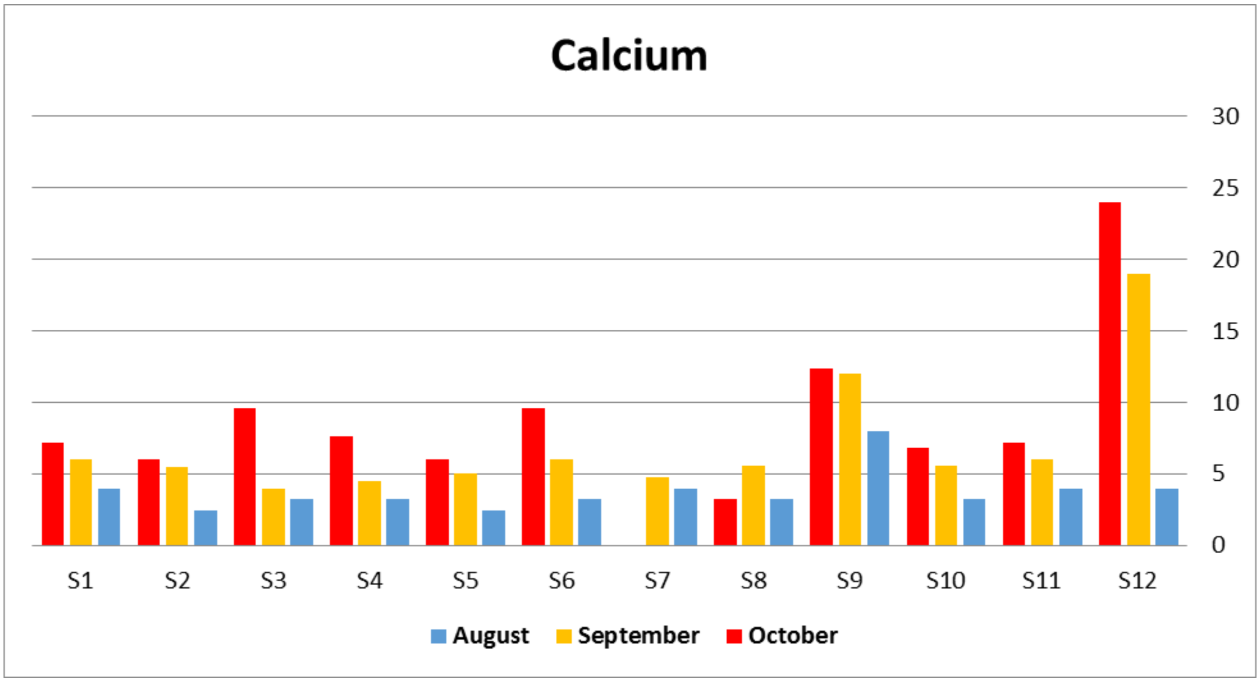

Figure (7): Calcium Rates for Study Sites

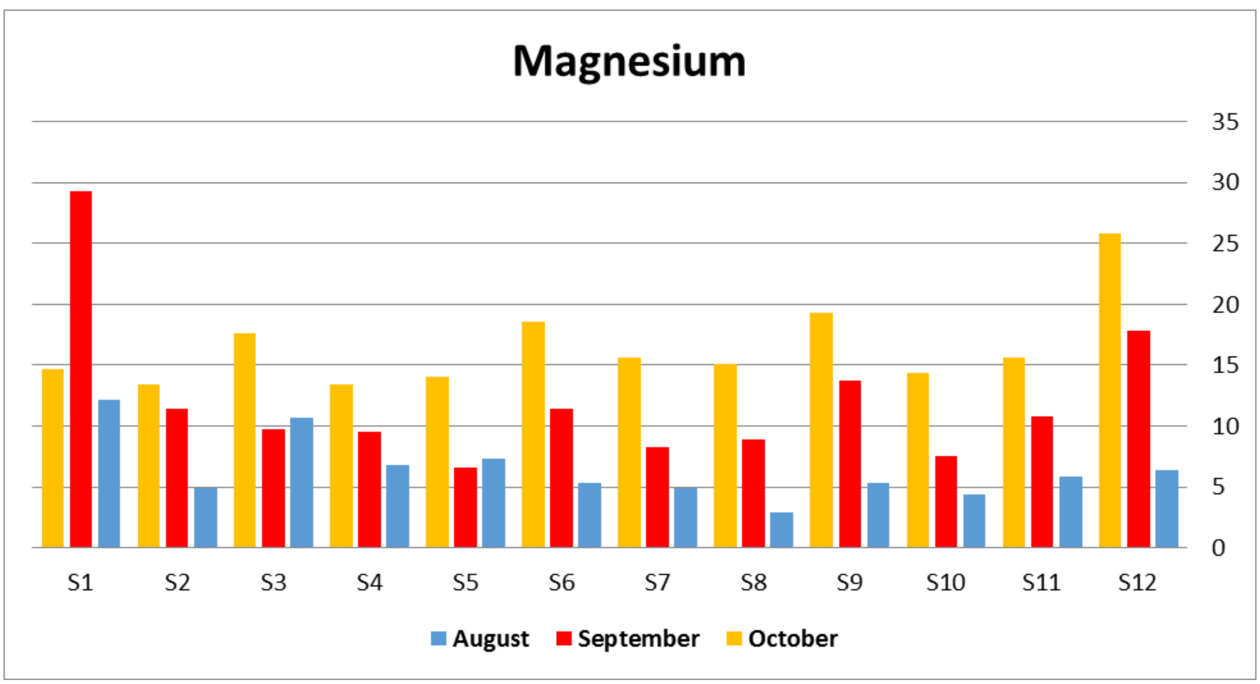

Figure (8): Magnesium Rates for Study Sites

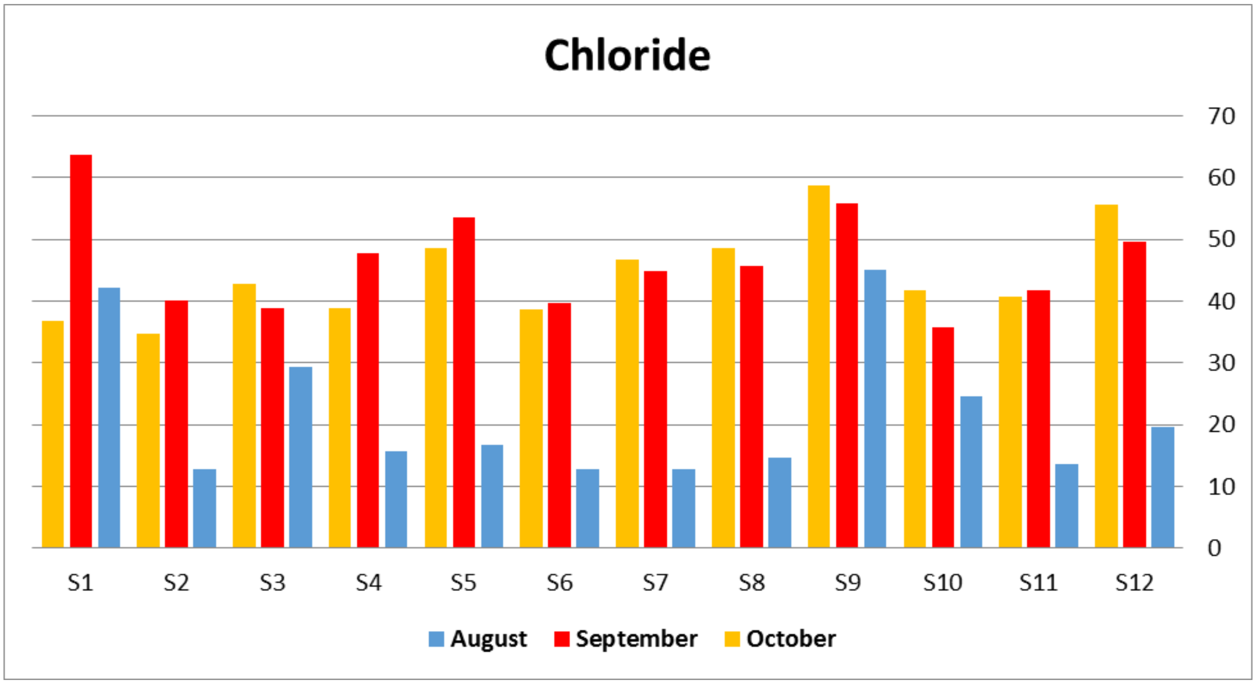

Figure (9): Chloride Rates for Study Sites

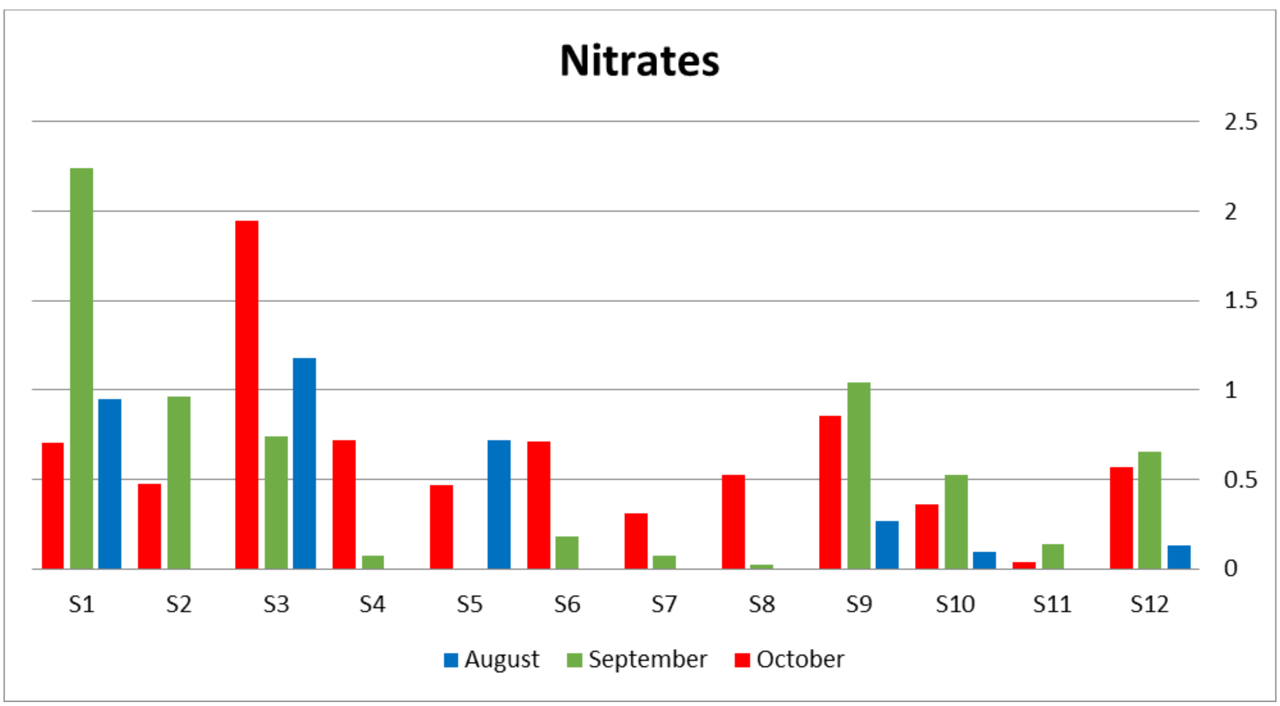

Figure (10): Nitrate Rates for Study Sites

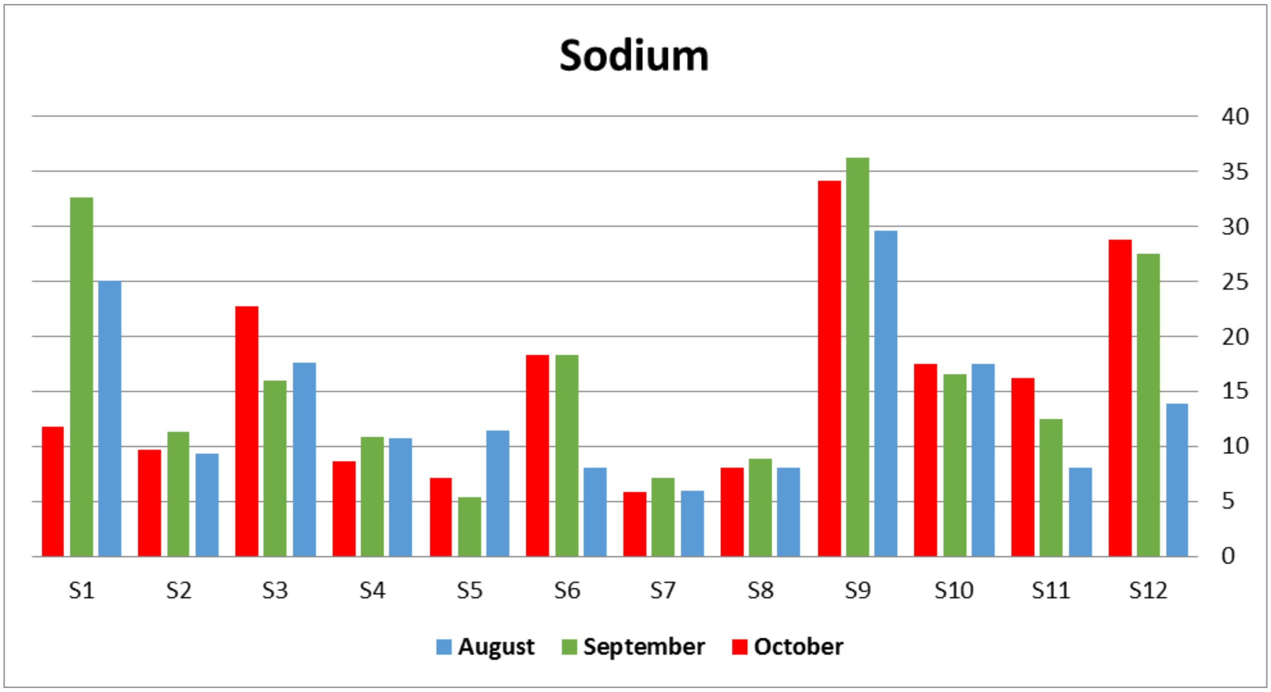

Figure (11): Sodium Rates for Study Sites

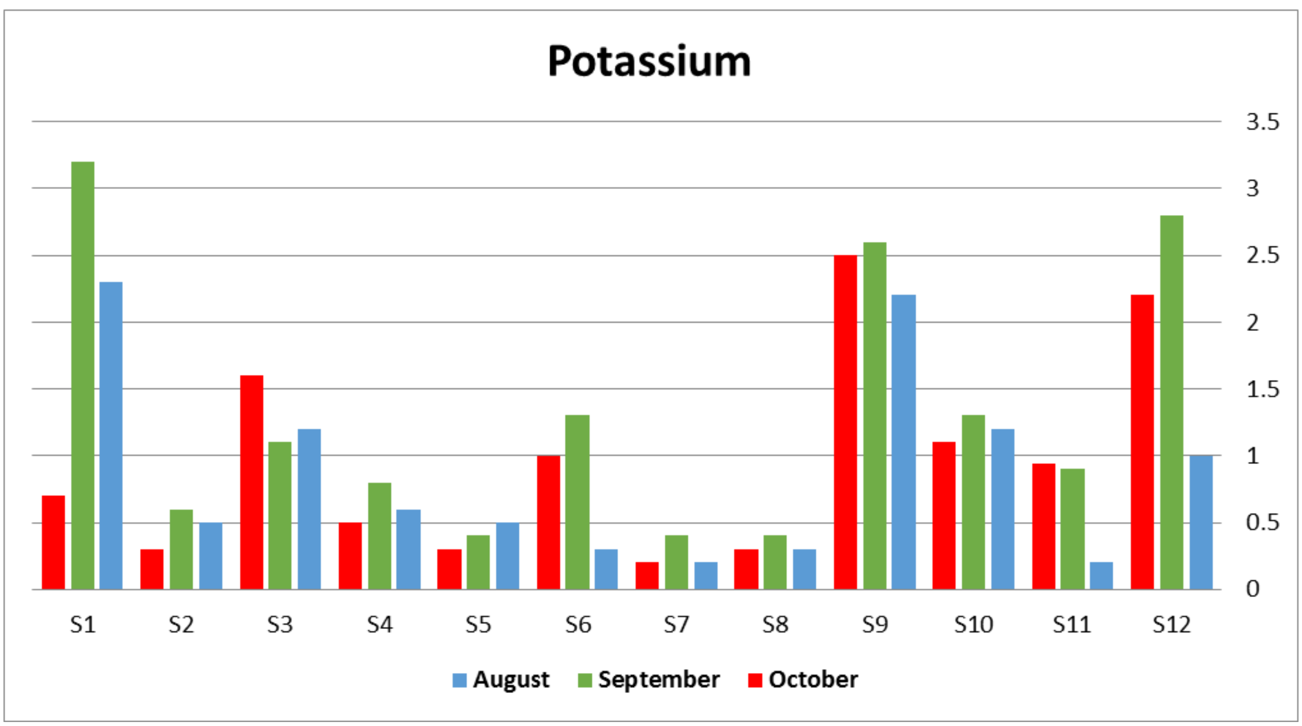

Figure (12): Potassium Rates for Study Sites.

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