Qualitative assessment of groundwater for livestock and poultry watering: A case study of water wells in Hamdaniya district, Nineveh governorate, Iraq.

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Abstract
During the study, a field survey was conducted for villages, fields and farms in the Hamdaniya area that use well water. Twenty wells were identified to collect water samples during the dry season to assess the physiochemical properties of the water, and a weighted mathematical model was applied to assess water quality for the purposes of watering livestock and poultry. The results indicated that the water quality index values fluctuated between (33.0 to 282) due to the different geological formations that the water passes through, as 45% of the water samples were from the Unfit category, 25% from the water category of poor quality, and the rest (30%) were from the good water category for watering livestock and poultry.

Keyword: quality of livestock drinking water, (WQI), Al-Hamdaniya district.

1. Introduction
Water is life, health, and wealth, and it is a blessing from God, and tampering with water resources is one of the grave breaches that reflect on human health, economy, and development. Today, the problem of pollution and water shortage has become one of the most important and sensitive problems in the world and unfortunately, it has not been dealt with well in many countries of the world, especially the third world countries, including Iraq, due to the random increase of industrial, agricultural and civil activities, which led to a decrease in the amount of water suitable for human consumption [1]. The use of safe drinking water is very necessary for humans and animals. Unfortunately, many people do not care about the drinking water of livestock and poultry, so they are forced to drink from polluted ponds and contaminated water despite their lack of taste, which affects the health and productivity of livestock and poultry, which has an economic return to the country [2,3,4].

For example, heat stress has a negative impact on the behavior and health of animals. The high summer air temperature, as is the case in Iraq, will lead to an increase in the animal’s body temperature, an increase in the respiration rate (RR), heartbeat, and an effect on hormonal systems and the immune system, which will negatively affect the efficiency of reproduction and the productivity of meat, milk and eggs. Therefore, animals and livestock resort to drinking relatively cold water (as is the case in well water) to reduce heat stress [5].

Studies indicate a strong relationship between drinking water quality and production for livestock and poultry. As the rate of weight gain is 25% for cows that drink clean water compared to cows that drink contaminated water, and this is what [6] indicated, where they found a significant increase in the weights of animals such as meat cows and calves compared to their counterparts that drink contaminated water and attributed this to the effect of pollutants and pathogens. Therefore, livestock and poultry must be protected from drinking contaminated water because it contains water-borne disease such as E. Coli, Salmonella spp., Campylobacter sp., viruses and parasite ... etc, which affects the health and productivity of animals and the possibility of their transmission to the human consumption of animal products [7].

Likewise, the salinity of water affects as it affects the productivity of cows from milk and fat, and during pregnancy and lactation, animals are more sensitive to salts, which causes them to have many pathological symptoms. They also affect the growth and production of poultry and chickens, and this effect increases in the summer compared to winter because the temperatures Low winter season reduces the negative effects of salt on the health and production of livestock and poultry[8,9]. Also, The acidic function of water affects the health and productivity of animals, at a pH of less than 5.5, problems related to Acidosis Mild occur, leading to a decrease in milk production and a decrease in the percentage of fats in it, but at a pH of more than 8.5, it causes problems related to Alkalosis for animals and lack of vitamin B and amino acids and problems. In the digestive system, diarrhea, as well as a lack of water and food intake, and thus lower productivity [7,9]. As for the high concentration of sulfate in animal drinking water, especially if the accompanying cation is magnesium, it causes...
diarrhea and a loss of desire to drink water and may lead to paralysis in young calves in advanced cases as a result of damage to the animal’s brain [10]. As a result of the lack of such studies in Iraq, despite their importance to the economy and national food security, this study aimed to assess the quality of groundwater in the Hamdaniya district for livestock and poultry watering.

2. Materials and Methodology

The study area: Most of the population centers of Al-Hamdaniya district (Qarqosh) are of an agricultural nature that depends mainly on groundwater for irrigation and watering of livestock and poultry. The region is characterized by the presence of hills in the northern and eastern parts and flat areas with some slight slopes towards the southwest [11], and it is located between longitude (43°23’23” to 43°21’44.3”) in the east and two lines of latitude (36°16’48.3” to 36°15’37.5”) to the north. Twenty wells have been randomly identified, which are of the type of deep wells to exceed the depths of most of them 20 m [12], as shown in Figure (1). As for the geological formation of the Hamdaniya district, it contains the Palaspi formation (Middle-Upper eocene), which consists of limestone (CaCO₃), the formation of Al-Fatha (Middle-miocene) that contains limestone and gypsum rocks (CaSO₄·2H₂O), anhydrite (CaSO₄), evaporated salts and yellow marl, the formation of Anjana (Upper Miocene) consisting of sandy and alluvial layers and sometimes clay and the Muqdadiyah formation (Pliocene), as deposits of gravel and sand appear in the area [13]. Water samples were collected for physiochemical tests at the rate of one sample per month from each well (from April to June) using clean bottles of polyethylene that were field-washed with sample water, and in the laboratory the pH was measured with a pH meter after calibrating it with multiple standard buffer solutions, electrical conductivity using an EC-meter after calibration and temperature correction. In addition to measuring anions and cations according to international standard methods [14,15].

2.1. Calculation of water quality index (WQI)

The water quality index (WQI) is a good way to assess water quality for different uses as it expresses the interactions between the studied parameters to give a single value instead of the large number of data that are understood by everyone. The quality of drinking water for livestock and poultry is often neglected, especially in third world countries, as studies related to the quality of drinking water for livestock are very few.

Figure 1. A map of the Hamdaniyah district showing the locations of the studied wells.

so we decided to do this study. The weighted mathematical model was applied on ten parameters and compared with the global levels permitted for livestock and poultry drinking and the weights are given in Table 1 using the following equations [18, 19]:
Table 1. Permissible standard concentration (Sn*), Property weight (Wn) of nth property.

| Properties | Unite | Perm. Stand (Sn) | Weight Wn |
|------------|-------|------------------|-----------|
| PH         |       | 5.6              | 0.15938666667 |
| EC         | dS.m⁻¹| 1.600            | 0.0011954000000 |
| Ca         | ppm   | 100              | 0.01195400000 |
| Mg         | ppm   | 100              | 0.01195400000 |
| Na         | ppm   | 300              | 0.0039846666666 |
| K          | ppm   | 20               | 0.05977000000 |
| HCO₃⁻       | ppm   | 1000             | 0.0011954000000 |
| Cl         | ppm   | 300              | 0.0039846666666 |
| SO₄²⁻       | ppm   | 500              | 0.0023290800000 |
| NO₃⁻       | ppm   | 133              | 0.00089879799 |

Σ* [16,17]

\[ Wn = \frac{K}{Wn} \]

\[ Qn = \frac{100 [Vn – Vi]}{[ Sn – Vi]} \]

\[ WQI = \frac{\sum Qn \times Wn}{\sum Wn} \]

Where: K: Proportional constant., Wn: Property weight of nth parameter., Sn: Permissible standard concentration of nth parameter., Qn: The quality rating of nth parameter., Vn: measured value., Vi: the ideal value of ith parameter.

After finding the value of the quality index, the water is judged by comparison to Table (2) of the water quality classification [20].

Table 2. Water quality index categorization schema.

| Water quality index value | Water status |
|--------------------------|--------------|
| 0.0 - 25                 | Excellent    |
| 26-50                    | Good         |
| 51 - 75                  | Poor         |
| 76 - 100                 | Very P.      |
| >100                     | Unfit        |

3. Results and Discussions

The results are shown in Table (3, 4) indicate that the WQI values range from (282 to 33.0), as the highest values were in the studied water samples for well 7 and the lowest values in the well water samples 13, when comparing the results to Table (2) for the water classification, we find that 45% of the groundwater in the Hamdaniyah district was of the unfit water category (well water: 1, 2, 3, 4, 5, 6, 7, 8, 9) in which the water quality index values ranged between (136 to 282) and 25% of the studied groundwater is of poor quality (well water: 10, 11, 16, 18/19) in which the values of the water quality index ranged between (52.2 to 63.6) and this deterioration in the quality of 70% of the groundwater is attributed to high levels of electrical conductivity, which reached (4,032) dS .m⁻¹ and the concentrations of sodium, magnesium and sulfate ions to reach rates (704, 537, 2227) ppm consecutively, this increase in concentration may be due to the passage of water through the formation of Alfatha in the study area, which is rich in sediments of evaporation salts, gypsum and anhydrites (Kablan et al, 2018), as shown in Table (5), and consequently, the high (Qn) values for these properties were reflected in the high values of the water quality index (WQI).

The high concentration of dissolved sulfate ions in water is due to the possibility of reactions to the sulfur compounds present in the formation of Alfatha by the action of the sulfur bacteria (Thiobacillus denitrificatis) to form hydrogen sulfide, which is aerobically oxidized to sulfate ions (SO₄²⁻) as in the following equations [7, 21]:

\[ 2\text{CaSO}_4 + 3[\text{CH}_2\text{O}]_{\text{Bacteria}} \rightarrow 2\text{CaCO}_3 + 2\text{S} + \text{CO}_2 + 3\text{H}_2\text{O} \]

\[ \text{S}^+ + 2\text{H}^+ \rightarrow \text{H}_2\text{S} \]

\[ \text{S}_2\text{O}_3^2+ + 2\text{H}_2\text{O} \rightarrow 2\text{SO}_4^{2-} + 2\text{H}_2\text{O} \]

Likewise, the relatively high concentration of bicarbonate ions, especially water wells (2, 7, 5, and 3) is due to the reactions that take place in water containing carbon dioxide as it passes through the ground layers, which leads to the transformation of insoluble calcium carbonate into dissolved bicarbonate, as in the following equations [22,23,24]:

\[ 2\text{CaCO}_3 + 2\text{H}_2\text{O} \rightarrow 2\text{Ca}^{2+} + 4\text{OH}^- + \text{CO}_2 \]
While no concentration of carbonate ion was observed in all the studied aqueous samples, this confirms that the pH values did not exceed 8.3 [25]. It is noted that the studied well water was characterized by a small fluctuation range in the values that ranged between (7.05-7.8), which is within the appropriate levels for livestock and poultry watering. This is attributed to the ability of the acid neutralization capacity (ANC) for water and soils rich in bicarbonate and carbonate salts [1]. Without this ability, the changes in values would have been greater than that, and thus the effect on the health and productivity of the livestock and poultry consumed. Finally, the results are shown in Table (5) indicated a relative improvement in the quality of water for 30% of the studied water samples, which included well water (12, 13, 14, 15, 17, 20), so that the WQI values did not exceed (63.6). The water of these wells is of good quality for watering livestock and poultry, and this quality improvement is due to the decrease in the concentrations of the most studied characteristics, which are due to the nature of the geological formations that passed through them as the Anjana and Palasapi formations.

| Table 3. Results of quality rating (Qi) and water quality index values. |
|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Wells Properties     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
| pH                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| EC                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Ca                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Mg                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Na                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| K                    | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| HCO₃                 | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Cl                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| SO₄                  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| NO₃                  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Σ Qn x Wn            | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| WQI values           | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Water quality        | Unfit | Unfit | Unfit | Unfit | Unfit | Unfit | Unfit | Unfit | Unfit | Unfit |

| Table 4. Results of quality rating (Qi) and water quality index values. |
|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Wells properties     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
| pH                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| EC                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Ca                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Mg                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Na                   | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  | Qn  | Wn  | Qi  |
| Propert. Wells | pH | EC$_{25}$ | Ca | Mg | Na | K | HCO$_3$ | Cl | KCl | SO$_4$ | Cl | NO$_3$ | Depth |
|---------------|----|-----------|----|----|----|---|--------|----|-----|--------|----|--------|-------|
| mean          | 7.44 | 3.035 | 529 | 214 | 131 | 41 | 199 | 213 | 1477 | 4.90 | 25.0 |
| +Sd           | 0.04 | 0.049 | 28  | 17  | 3.7 | 6.2 | 3.04 | 9.0  | 563  | 0.03 |
| mean          | 7.05 | 3.634 | 432 | 361 | 221 | 33 | 355 | 183 | 1632 | 5.57 |
| +Sd           | 0.12 | 0.218 | 22  | 3.7 | 4.0 | 2.7 | 1.00 | 6.5  | 445  | 0.13 |
| mean          | 7.42 | 4.032 | 392 | 487 | 391 | 5.9 | 433 | 508 | 2147 | 6.98 |
| +Sd           | 0.11 | 0.317 | 28  | 4.0 | 9.4 | 1.0 | 18.4 | 8.5  | 231  | 0.10 |
| mean          | 7.20 | 3.152 | 334 | 278 | 182 | 18 | 314 | 339 | 1517 | 4.00 |
| +Sd           | 0.16 | 0.267 | 33  | 3.8 | 5.0 | 1.3 | 15.0 | 26  | 513  | 0.16 |
| mean          | 7.09 | 2.941 | 259 | 246 | 175 | 7.4 | 325 | 320 | 1245 | 3.49 |
| +Sd           | 0.07 | 0.272 | 59  | 43  | 3.0 | 0.4 | 16.0 | 32  | 242  | 0.10 |
| mean          | 7.15 | 3.738 | 386 | 420 | 368 | 9.8 | 322 | 267 | 1629 | 3.00 |
| +Sd           | 0.01 | 0.746 | 25  | 37  | 14  | 1.6 | 9.26 | 26  | 244  | 0.22 |
| mean          | 7.54 | 5.440 | 450 | 537 | 704 | 14 | 365 | 362 | 2227 | 2.99 |
| +Sd           | 0.26 | 0.543 | 47  | 48  | 50  | 0.7 | 31.6 | 47  | 408  | 0.09 |
| mean          | 7.28 | 3.829 | 526 | 319 | 138 | 4.4 | 271 | 135 | 1488 | 3.99 |
| +Sd           | 0.19 | 0.583 | 60  | 6.2 | 12  | 0.5 | 9.67 | 4.3  | 497  | 0.09 |
| mean          | 7.18 | 2.709 | 493 | 156 | 92  | 7.0 | 306 | 210 | 1270 | 15.7 |
| +Sd           | 0.04 | 0.183 | 51  | 55  | 2.3 | 2.5 | 22.0 | 19  | 257  | 0.53 |
| mean          | 7.44 | 1.380 | 139 | 98  | 99  | 5.2 | 253 | 56  | 698  | 2.34 |
| +Sd           | 0.18 | 0.107 | 38  | 32  | 2.3 | 0.9 | 9.81 | 4.1  | 74   | 0.1  |
| mean          | 7.55 | 0.974 | 37  | 47  | 89.0| 1.95| 246 | 32  | 236  | 3.85 |
| +Sd           | 0.22 | 0.092 | 7.1 | 7.7 | 10.6| 0.55| 48.2 | 5.2  | 44   | 1.50 |
| mean          | 7.82 | 0.856 | 36  | 26  | 94.3| 6.63| 193 | 36  | 184  | 1.71 |
| +Sd           | 0.33 | 0.068 | 0.3 | 3.3 | 2.53| 0.47| 11.2 | 2.5  | 33   | 0.34 |
| mean          | 7.80 | 0.510 | 37  | 20  | 38.0| 2.07| 167 | 17  | 94   | 11.9 |
| +Sd           | 0.38 | 0.039 | 6.8 | 2.3 | 1.00| 0.20| 11.5 | 1.0  | 17   | 5.00 |
| mean          | 7.60 | 0.728 | 66  | 32  | 31.1| 2.34| 245 | 34  | 174  | 1.10 |
| +Sd           | 0.29 | 0.080 | 13  | 11  | 1.00| 0.47| 31.0 | 17  | 23   | 0.05 |
| mean          | 7.39 | 0.713 | 61  | 35  | 39.1| 2.54| 207 | 27  | 159  | 2.39 |
| +Sd           | 0.28 | 0.027 | 9.3 | 4.5 | 2.07| 0.55| 36.5 | 5.4  | 40   | 0.83 |
| mean          | 7.85 | 0.918 | 53  | 41  | 92.0| 16.8| 266 | 23  | 263  | 0.90 |
| +Sd           | 0.11 | 0.011 | 0.9 | 1.7 | 2.76| 0.47| 748 | 1.8  | 78   | 0.04 |
| mean          | 7.41 | 0.673 | 54  | 39  | 40.7| 2.03| 307 | 30  | 105  | 0.50 |
| +Sd           | 0.20 | 0.018 | 4.9 | 6.1 | 2.30| 0.16| 15.6 | 3.9  | 11   | 0.02 |
| mean          | 7.76 | 1.165 | 69  | 42  | 96.6| 2.07| 205 | 164 | 290  | 0.00 |
| +Sd           | 0.28 | 0.033 | 14  | 9.4 | 2.76| 0.66| 20.3 | 58   | 45   | 0.05 |
| mean          | 7.69 | 0.996 | 58  | 37  | 77.5| 4.41| 214 | 58  | 221  | 0.86 |

Table 5. The mean and standard deviation of the results of water analysis of Al-Hamdaniya district wells (ppm except EC in dS m$^{-1}$ and depth in m).
Conclusions and recommendations

The high levels of electrical conductivity and sodium, magnesium, and sulfate ions for most of the studied well water exceeded the permissible limits for watering livestock and poultry, which led to a high quality rating (Qi), which was negatively reflected on the WQI values. Therefore, we recommend conducting scientific studies on the effect of such quality of water on Iraqi livestock and poultry, with educating livestock and poultry farmers about the importance of using clean water to increase the productivity of animals such as meat, milk, and eggs.

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References

[1] Al-Shanona, R. A. A., Al-Sardar, N. M. S. and Al-Saffawi, A. Y., T. (2018). Water quality assessment for irrigation and livestock drinking in Abu Maria village/district of Tall-Afar-Iraq. J. of Environ. Studies [JES], 18: 9-14.
[2] Al-Saffawi, A. Y., Al-Assaf, A. Y., and Talat, R. A. (2020b). Valuation of water quality for livestock and poultry watering: a case study of groundwater in some areas of Mosul city, Iraq. Nippon J. of Environ. Sci., 1(2): 1006-1013. doi.org/10.46266/njes.1006
[3] R. H. Al- Qasimi, S. M. Abbas and A. L.D. Al-Khauzai. (2020). Effect of breed and some non - genetic factors on milk production and some proportions of its chemical components in two breeds of local sheep. Al-Qadisiyah J. for Agric. Sci. (QAS). 10(1): 227-231. http://qu.edu.iq/jouag/index.php/QJAS/index
[4] A. L. D. Al-Khauzai. (2020). The Effect of Crossbreeding on Some Economic Traits for Chicks of Lohmann Chicken. Al-Qadisiyah J. for Agric. Sci. (QAS). 10(1): 221-226. DOI: https://doi.org/10.43794/qjas.Vo10.Iss1.101
[5] N. Das., P. Monda., R. Ghosh and S. Sutradhar. (2019). Groundwater quality assessment using multivariate statistical technique and hydro-chemical facies in Birbhum District, West Bengal, India. SN Applied Sciences, 1(8): 1-21. https://doi.org/10.1007/s42452-019-0841-5
[6] Dreebi, H. A. & Abdul Razak,N.A. (2020). The Impact of Corruption on Agriculture Sector in Iraq: Econometrics Approach. IOP Conference Series: Earth and Environmental Science. 553(1).
[7] N.A.S. Al-Hamdany. (2020). Application of water quality index to assess the quality of some wells water in the left side of Mosul city / Iraq M.Sc. Thesis. College of Environ. Techn. Mosul University. Iraq (In arabic). DOI: 10.13140/RG.2.2.36565.24807.
[8] Tausifi, M.A., Shahzad, F., Bhatti, J.A., Qamar, S., Khaliq, A., Rahman, H., Ali, H.M., Hussain, A. (2018). Effect of water quality on production performance of lactating Nili-Ravi buffaloes. Turkish Journal of Veterinary and Animal Sciences.,42,543-548. doi:10.3906/vet.1703-88
[9] A.Y.T. Al-Saffawi, A. Y.R. Al- Assaf1, R. A. Talat (2020c). Valuation of water quality for livestock and poultry watering: a case study of groundwater in some areas of Mosul city, Iraq. Nippon J. of Envi. Sci. 1(2): 1-7. doi.org/10.46266/njes.1006
[10] Olayiwola, H. A., Adewuyi, K. G., and Ademola, A. (2020). Physicochemical Assessment of Groundwater Quality from Hand Dug Wells and Boreholes of Part of Mokola-Eleyele, Ibadan Metropolis, Southwest Nigeria. International Journal of Advanced Engineering, Management and Science, 6(2):80-90.
[11] N.H. Ac-Saigh, Y. F. Elimes and Z. D. Al-Shaikh. (2011). Stratigraphical and structural geology of Handamia area from geoelectrical study,Iraqi National J. of Earth Sci.11(2): 1-14.
[12] A.Y. T. Al-Saffawi, B. S. U. Ibn Abubakar, L.Y. Abbass and A. K. Monguno. (2020c). Assessment of groundwater quality for irrigation using water quality index in Al- Kasik sub district Northeastern of Mosul City. Iraq. Nigerian J. of Techno. (NIJOTECH). 39(2): 632 –638. http://dx.doi.org/10.4314/njt.v39i1.35
[13] F.A. Ibrahim, E. I. Ibrahim, V. K. Sissakain and N. A. Ali. (2000). Geological map of Iraq. Mining and general geological company, Baghdad. Iraq
[14] APHA, AWWA and WCPE. (1998). "Stand Method for Examination of water and wastewater American public Health Association , 20th ed., Washington DC, USA.
[15] APHA, AWWA and WCPE. (2017). "Stand Method for Examination of water and wastewater American public Health Association , 23RD ed., Washington DC, USA. https://doi.org/10.2105/SWWW.2882.216
[16] AYELOJA Ayodeji Ahmed. (2020). GLIMPSE OF FISH AS PERISHABLE STAPLE. Al-Qadisiyah Journal For Agriculture Engineering, Management and Science, 6(2):80-90.
[17] A. J. A. Al-Barzanji. (2020). Application of mathematical models(WQI) to evaluate the water quality of wells in Al- Rashidiya area, north of Mosul, for drinking, irrigation, watering of livestock and poultry. M.Sc. Thesis. Coll. Of Eduction for pure scince. Mosul Univer. Iraq
[18] N. B. Bhatti, A. A. Siyal and A. L. Qureshi. (2018) Groundwater quality assessment using water quality index: A Case study of Nagarparkar, Sindh, Pakistan. Sindh University Res. J.-SURJ 50(2), 227-234. doi.org/10.26692/suj/o/2018.06.0040
[19] Mohammed, M.A. (2020). Structural, Optical, Electrical and Gas Sensor Properties of ZrO2 Thin Films prepared by Sol-Gel Technique. Neuroquantology, 18(3), 22-27. doi: 10.14704/nq.2020.18.3.nq20146

[20] B. E. Chebet, J. K. Kibet and D. Mbui. (2020). The assessment of water quality in river Molo water basin, Kenya. Appl. Water Sci. 10:92-102. https://doi.org/10.1007/s13201-020-1173-8

[21] A.Y.T. Al-Saffawi and R.A. Talaat. (2018). Phytoremediation of domestic wastewater using Chara vulgaris algae. Int. J. of Enhanced Res. in Sci., Techn. and Eng, 7(10): 6 – 11.

[22] A.Y.T. Al-Saffawi, B.S.U. Ibn Abubakar, A.Y.R. Al-Asaat, M. Hussaini and U.A. Ibrahim. (2020d) Groundwater quality assessment of Nimrod for livestock and poultry Uniport J. of Engin. and Sci. Res. (UJESR). 5(Special https://www.researchgate.net/publication/344193177

[23] M.H.S. Al-Mashhdany, J.A.A. Al-Mamaree and A.Y.T. Al-Saffawi. (2020). Valuation of water for drinking and domistic purposes using (WQI). Case study: Groundwater of Abu-Wagnah village, Tal-Afar district, Iraq. Plant Archives. 20(2): 3924-3928.

[24] A.Y. T. Al-Saffawi, M. A. Bhat and A. A. Albaker.(2020e). Assessment of Groundwater for Irrigation Using (IWQI) Model, Located in Al-Nimrud Region at Southeastern of Mosul City, Iraq. Pak. J. Anal. Environ. Chem. Vol. 21, No. 2 (2020) 349 – 357. http://doi.org/10.21743/pjaec/2020.12.37

[25] Al-Sinjari , W.E., Al-Saffawi ,A.Y.T., and Al.Taei, Y.A.J. (2019). Application of WQI Model to Assessment of water for irrigation and livestock drinking purpose: the case study . Groundwater quality of Gleewkhan village southeastern of mosul city. Iraq. Journal of Engineering and Applied Sciences. 14( 9): 10706-10710.