Life Science Informatics Publications

Research Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences

Journal Home page http://www.rjlbpcs.com/

RJLBPCS

ISSN 2454-6348

Original Research Article **DOI: 10.26479/2018.0405.26**

THE PROBLEM OF SALT WATER INTRUSION IN THE FIRST COASTAL AQUIFER OF KOTA BHARU KELANTAN, MALAYSIA

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ABSTRACT: For optimal use and sustainability of water resources with a good quality; it requires adequate information on chemical and physical characteristics of surface and ground water. It can be through the regular monitoring operations. The Kota Bharu wells fields composed of three alluvial coastal aquifers. The second aquifer is brackish and interconnected with the third aquifer. The main purpose of this work was to investigate the impact of the salt water intrusion into the shallow aquifer, using physical and chemical characteristics of ground water. The results of physical measurements showed that, water level ranged from 0.35- 4.36 m, wells' total depth from 1.55-13.43 m, average of temperature 28.27℃ and average of electrical conductivity (EC) 293.75 µs/cm. Total dissolved solids (TDS) average 175 mg/L, salinity 0.127 and pH 6.50. The chemical parameters showed that a low average of Chloride (Cl), Sodium (Na), Sulphate (SO4), Magnesium (Mg), Calcium (Ca) and Potassium (K), which were 37.8, 42.11, 12.5, 4.7, 8.5 and 3.5 mg/L respectively. Generally, the ground water in the first aquifer is fresh, due to the very low average of chloride, salinity, total dissolved solids, and electrical conductivity except the well number (1). It is considered saline due to the high average of chloride, salinity, total dissolved solids, and electrical conductivity. This well (1) represents the salt water intrusion area due to its location very close to the sea at Dasar village about 83 m from the sea and due to the over extraction of ground water from this area.

KEYWORDS: Saltwater intrusion; First aquifer; Kota Bharu.

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1.INTRODUCTION

Issues related to water resources management are the most global concern and more attractive to the water resources researchers. These issues have advanced due to the increasing demand for water as result of an escalation of population. One of the sources of fresh water can be gotten from ground water [1]. Abstraction of the ground water is the only method to meet the drinking water demand and domestic use [2]. Water wells are renewable natural resources and are vital to human as it is used for domestic applications [3]. Moreover, the ground water is very valuable throughout the globe because people worldwide still depend on the ground water as their source for drinking water and domestic use. The ground water quality has become a great concern because there are several issues that can deteriorate its quality. Some of the issues are the rapid growth of urban regions which can lead to over exploitation of the resources; improper agricultural and waste disposal performs [4]. Generally the ground water is less contaminated compared to surface water; due to the filtration process during the flow of ground water through rocks and soil, which can filter the greatest amount of the pollutants presents in ground water [5, 6]. The ground water is the main source of water supply in Kota Bharu, which contributes 47% of the total water supply and constitutes about 99% of the total potable demand in North Kelantan. The ground water is mainly used for drinking water supply, as well as for industrial and agricultural purposes. The sustainable management, maintaining and protecting the ground water resources are the main concern as about 75% of the inhabitants live in North Kelantan which represent 17% of the total area. These challenges have produced the need to find appropriate ways for monitoring the extent of such environmental damage [7-9]. The most significant parameters that affect the ground water are the electrical conductivity (EC), total dissolved solids (TDS), calcium (Ca2), magnesium (Mg), sodium (Na) and chloride (Cl). These six parameters that greatly influenced the ground water characteristic are believed to be contributed by sea water [10]. The main issue with the Kota Bharu wells fields is the salt water intrusion into the second aquifer and has intruded to the third aquifer in some places because they are interconnected. Therefore this study is a strategic management process for water resources to discover whether there is an influence of the salt water intrusion into the first aquifer using physical and chemical characteristics of ground water based on GIS application.

2. MATERIALS AND METHODS

Study area

The investigated area is located on the North east coast of Peninsular Malaysia, situated along the coastal plain of north Kelantan (Figure1). It covers an area about 20 km long and 10 km wide between Tawang and the Kelantan River in north east Kelantan.

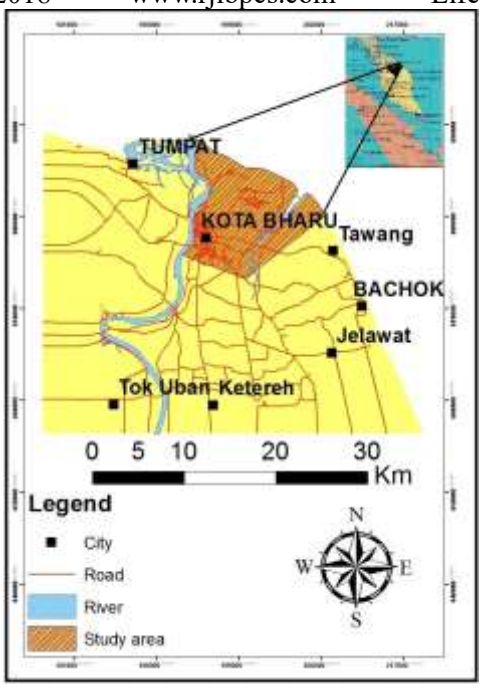

Figure 1: Location of the study area. Source: Redrawn from [18].

Geological and geomorphological condition

The study area represents the flat Kelantan alluvial plain. The Kelantan plain is covered with Quaternary sediments (Figure.2) overlying granite bedrock. It is drained by short river and stream which flow into the South China Sea. The central part of the plain is drained by the largest river in the region, the Kelantan River, and in the south east, it is drained by the Pengkalan Datu River. A broad division of the alluvium into marine and fluvial origin has been proposed but intermixing of positional processes [11].

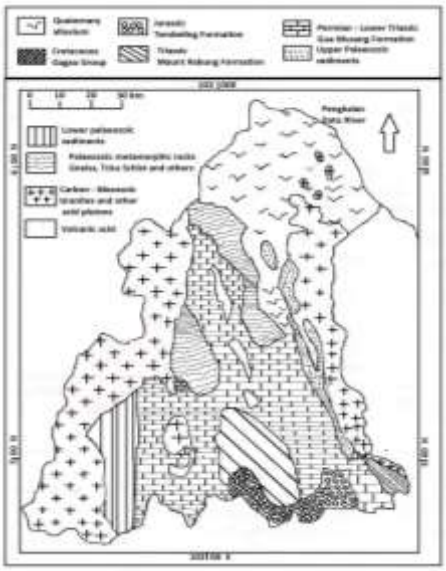

Figure 2: Geological map of the study area. Source: Redrawn from [12, 13].

Hydrogeological condition

The Quaternary sediments in the study area Figure 3 composed of alternating layers of gravel, sand, silt and clay. Deep drilling shows that these sediments overlie granite bedrock. Up to four aquifers

are present within the Quaternary sediments. Silty clay layers separate these aquifers from each other. The topmost is between a few meters to a maximum 15 m below the ground surface and separated from the second aquifer by a layer composed mainly of clay. The second aquifer‘s depth is generally between 20 m to 35 m with a thickness approximately 15 m. Once again a clay-rich layer separates this aquifer from the third aquifer below it. The depth of third aquifer is generally greater than 40 m and it also exhibits considerable thickness exceeding 50 m in some boreholes. Immediately overlying the granite bedrock is the fourth aquifer, which not always detected.

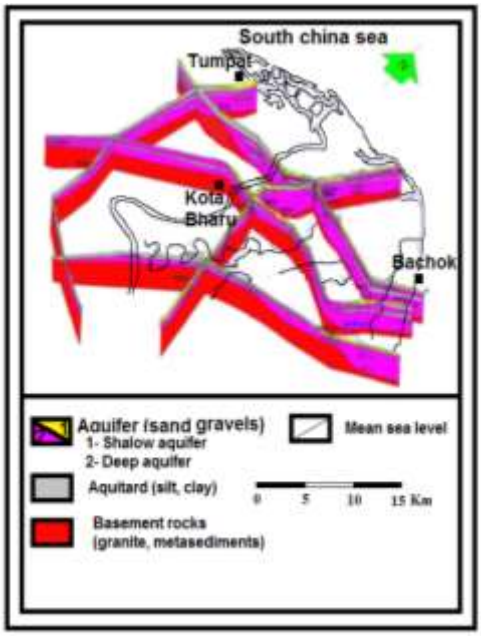

Figure 3: Fence diagram of Kelantan River Delta. Source: Redrawn from [14].

Water supply system

Most of the population in north Kelantan especially in villages gets their water supply either from the nearest stream and rivers or from the traditional wells, the traditional technique still flourishes. The Kota Bharu water works department is the sponsor of the ground water supply distribution system, which is now under the management of the Malaysian Public works. The first water resources study in the area of Kelantan was conceded by the German consultants in collaboration with the Geological Survey Department of Malaysia [15, 16]. A local contractor, Binner and Partners (Malaysia), was given a contract to explore the future water demand and recommend the best means of meeting the demand [17]. The public Water works Department typically gets ground water from the first and third aquifers. The ground water from the second aquifer is not utilized because it is brackish and not suitable for domestic purposes [18].

Hydro-physiochemical data

Two types of surveys were carried out within the study area at sites. Thirty seven ground water samples were obtained for hydro-chemical analysis at 37 test sites from shallow wells, on the first aquifer Figure 4.

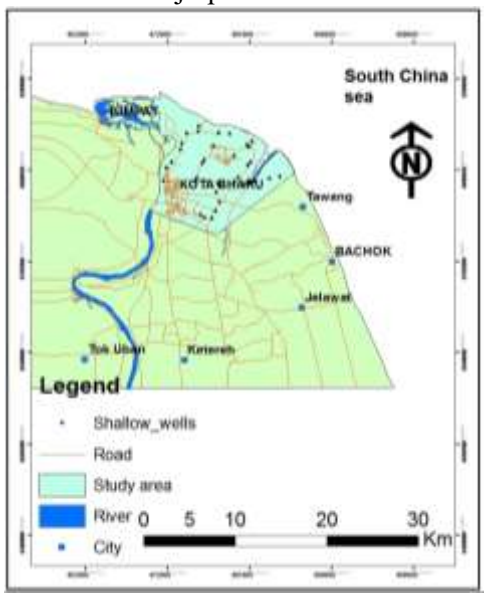

Figure 4: Special distribution map of the shallow wells in the first aquifer of Kota Bharu Source: Redrawn from [11].

Hydro-physical survey to determine the total depth of wells, water level, temperature of ground water (C˚), electrical conductivity (EC) µs/cm, total dissolved solids (TDS) mg/L, Salinty % and PH) were carried out in the field, whereas the chemical survey to determine concentration of (Ca, Na, Cl, and SO4) were analyzed in the laboratory. Quantitative data from (Cl), (EC) and (TDS) were used to produce the salinity map using GIS application.

3. RESULTS AND DISCUSSION

The results of hydro-physical and hydro-chemical analysis for thirty seven ground water samples, collected from the shallow wells in Kota Bharu and the surrounding area are represented in Figures (5-14). During the dry season, the water level in the wells ranged from 0.35- 4.36 m and from 0.5-4.34 m during the wet season. The variation in the water level refers to the hydrogeological and geomorphologocal conditions, besides that the climatic conditions and extraction rate of ground water in each area. The total depth average of the wells, ranged from 1.55 -13.43 m, depends upon the topography, geology and the thickness of this aquifer. The average of temperature was 28.27℃ during the dry season and 27.96℃ during the wet season. The electrical conductivity average was 282 µs/cm during the dry season. The highest value was 1367 µs/cm at the well (1) due to its location in Dasar village about 83 m from the sea, the lowest value was 1 µs/cm at the well (5) in Kemumin attributed to its location, which relatively far from the sea about 2711 m as shown in Figure 5.

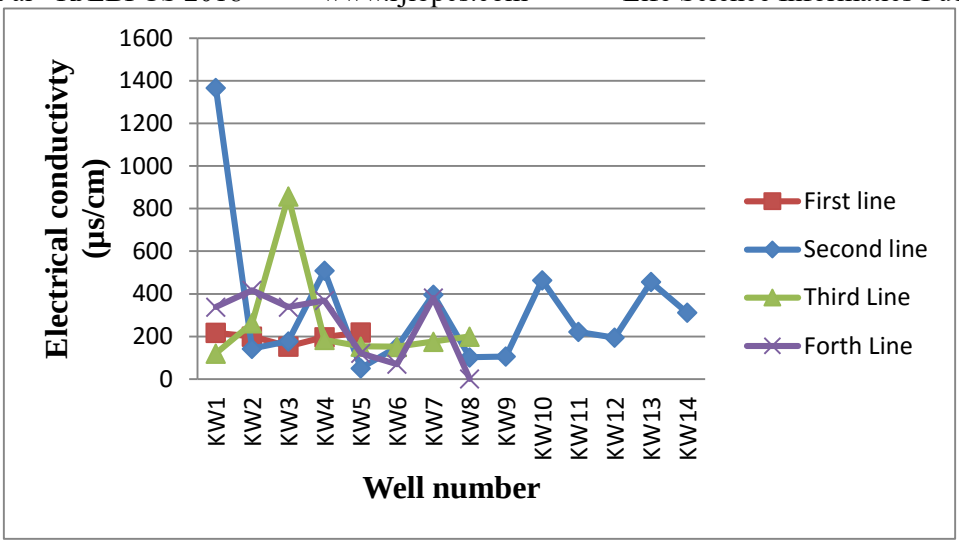

Figure 5: Variation of electrical conductivity in the wells during the dry season in the first aquifer of Kota Bharu

During the wet season, the (EC) average was 305.53 µs/cm the highest value was 1597 at the well (1) due to its location in Tibing Tinggi village about 850 m from the sea, the lowest value was 76 µs/cm at the well (4) in Tok Sadang which is relatively far from the sea about 2000 m as shown in Figure 6.

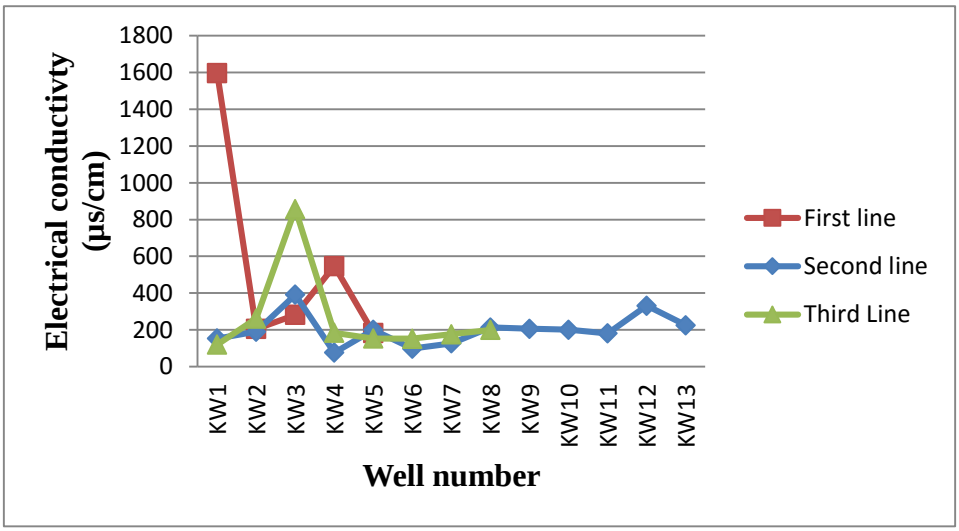

Figure 6: Variation of electrical conductivity in the wells during the wet season in the first aquifer of Kota Bharu

The total dissolved solids average was 172 mg/L during the dry season, the highest value was 830 mg/L at the well (1) due to its location in Dasar village about 83 m from the sea, the lowest value was 1 mg/L at the well (5) in Cang Ching attributed to its location (very far) from the sea about 8000 m as shown in Figure 7.

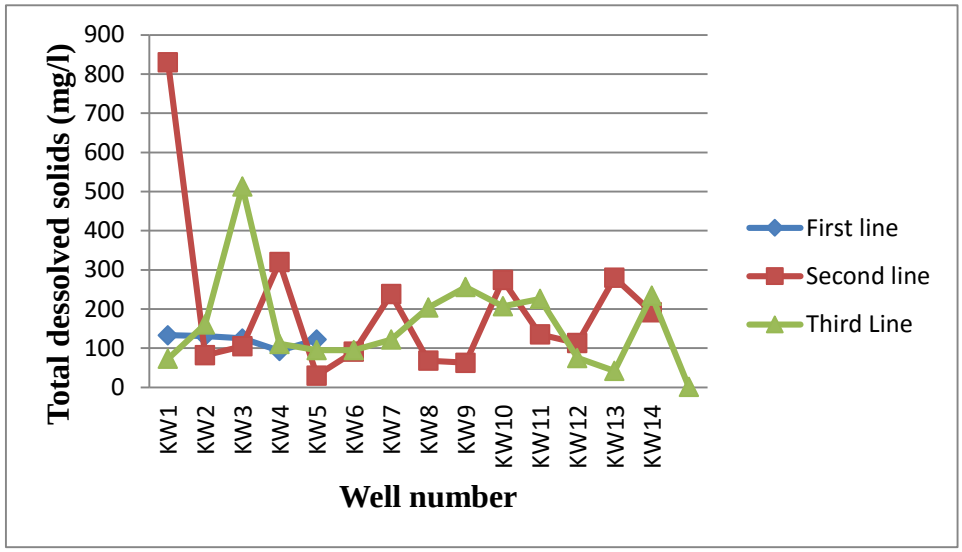

Figure 7: Variation of (TDS) concentration in the wells during the dry season in the first aquifer of Kota Bharu

whereas, during the wet season, the total dissolved solids average was 180 mg/L the highest value was 961 mg/L at the well (3) due to its location in Tebing Tinggi village about 850 m from the sea the lowest value was 47 mg/L at the well (2) in Badang attributed to its location which is about 1956 m from the sea Figure 8.

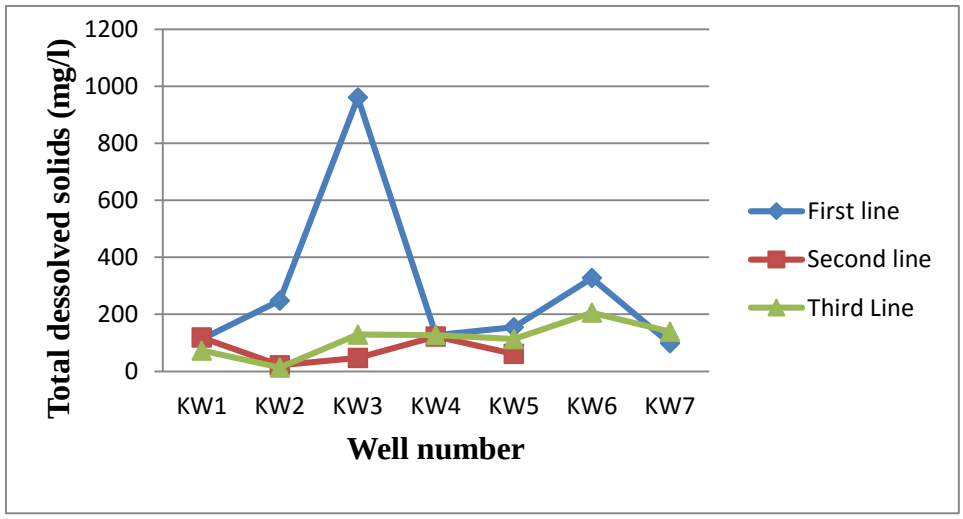

Figure 8: Variation of (TDS) concentration in the wells during the wet season in the first aquifer of Kota Bharu

The salinity average during the dry season was 0.129, the highest value was 0.63 at the well (1) due to its location in Dasar village about 83 m from the sea, the lowest value was 0.02 in the well (5) at the village of Kemumin about 2711m from the sea as shown in Figure 9.

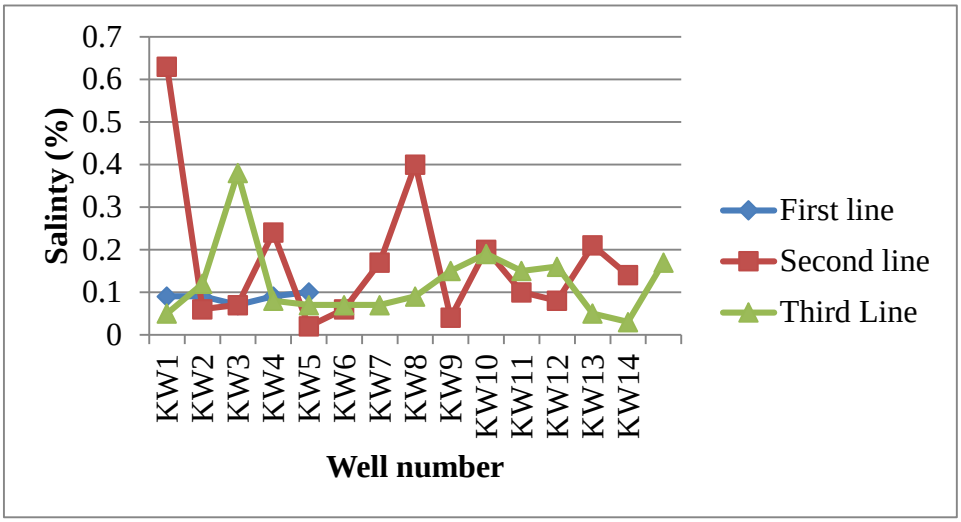

Figure 9: Variation of salinity concentration in the wells during the dry season in the first aquifer of Kota Bharu

During the wet season the salinity average was 0.134 the highest value was 0.74 at well (2) in Tebing Tinggi about 850 m from the sea. The lowest value was 0.03 at the well (5) in Tok Sadang village about 2000 m from the sea (Figure 10).

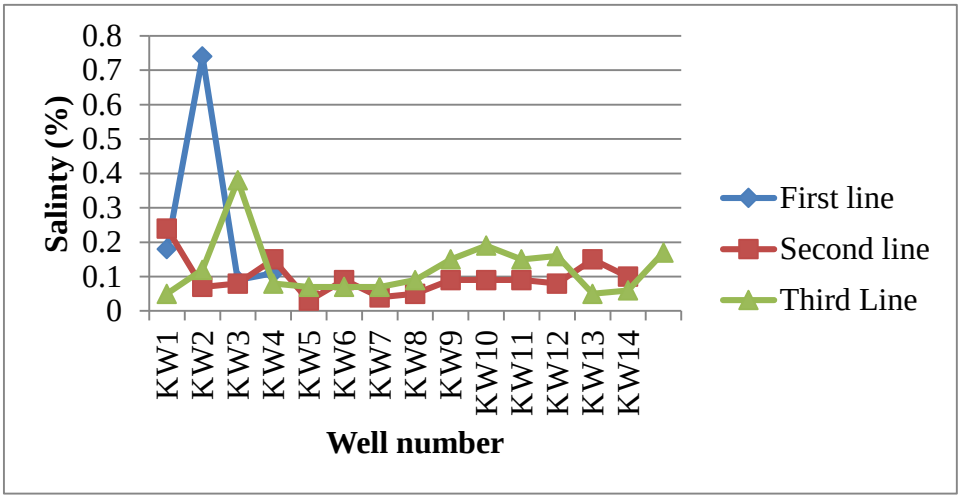

Figure10: Variation of salinity concentration in the wells during the wet season in the first aquifer of Kota Bharu

The average pH was 6.34 during the dry season, the highest value was 7.65 in the well (2) at Telok Kitang about 650 m from the sea, the lowest value was 5.55 in the well (28) at Gahay Bulan village about 677m from the sea. While, the wet season the average pH was 6.79 the highest value was 7.89 at the well (3) at the village of Tok Sadang about 2000 m from the sea. The lowest value was 5.5 at the well (7) at the village of Telok Kitang. Variation in the pH values is a result of some local impact factors, for instance local rocks, soil and vegetation cover. The chemical analysis results showed that, during the dry season the average of Na was 26.1 mg/L, the highest value was 59.89 mg/L in the wells (1) because it is very close to the sea about 83 m, at the village of Dasar. The lowest value was 1 mg/L in the well (7) at the village of Telok Kitang about 650 m from the sea Figure 11.

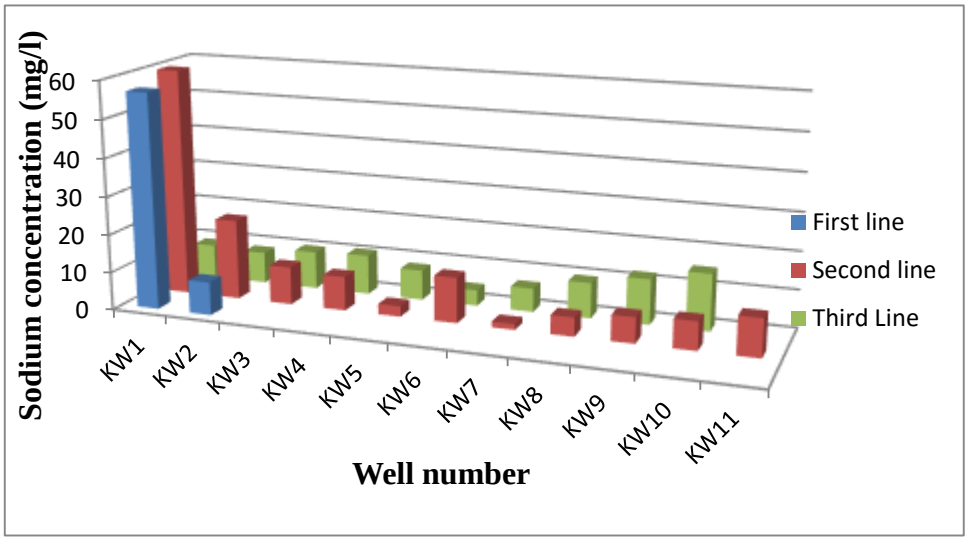

Figure 11: Variation of Sodium concentration in the wells during the dry season in the first aquifer of Kota Bharu

During the wet season, the Na average was 58.01 mg/L the highest value 675.60 mg/L in well (2) at Tebing Tinggi village. The lowest value was 3.60 mg/L in the well (10) at the village of Kemomin about 2711 m from the sea Figure 12.

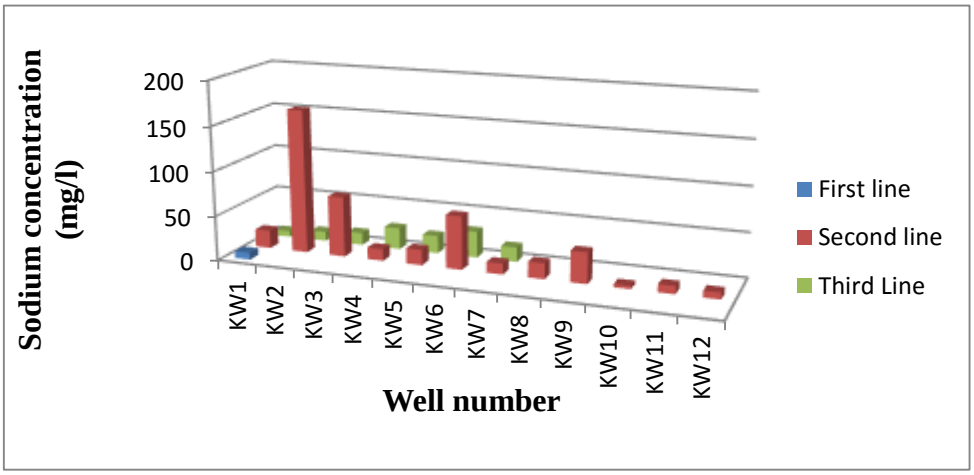

Figure 12: Variation of Sodium concentration in the wells during the wet season in the first aquifer of Kota Bharu

The average of Ca was 9.1 mg/L during the dry season; the highest value was 28.8 in the well (1) due to its location in Dasar village about 83 m from the sea. The lowest value was 0.24 mg/L at the well (8) at the village of Bancor about 4961m from the sea Figure 13.

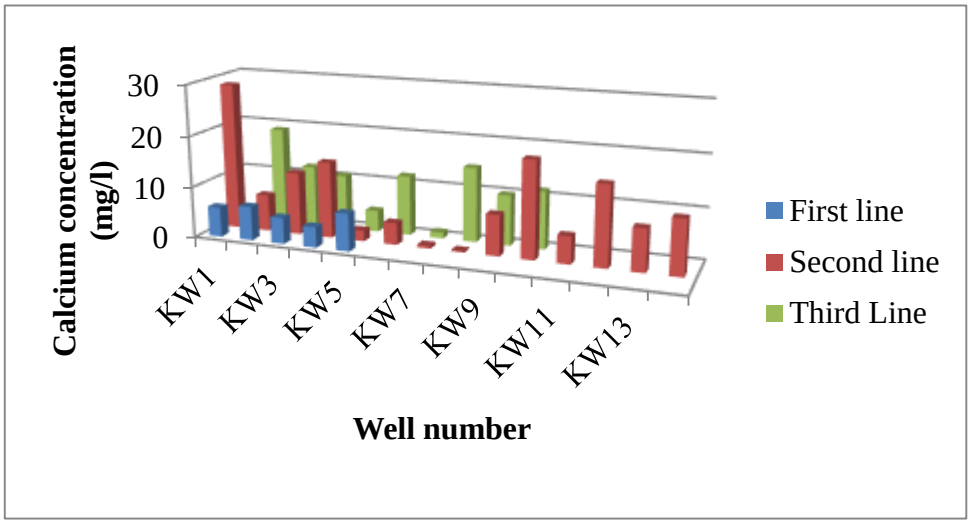

Figure 13: Variation of Calcium concentration in the wells during the dry season in the first aquifer of Kota Bharu

During the wet season the average of Ca was 7.9 mg/L. the highest value was 16.1 mg/L in the well (5) at the village of Cang Ching about 8000 m from the sea. The lowest value was 2.9 mg/L in the well (9) at the village of Gayang about 5846 m from the sea. Variation in Ca concentration average is attributed to the impact of the local rocks, soil and water usage Figure 14.

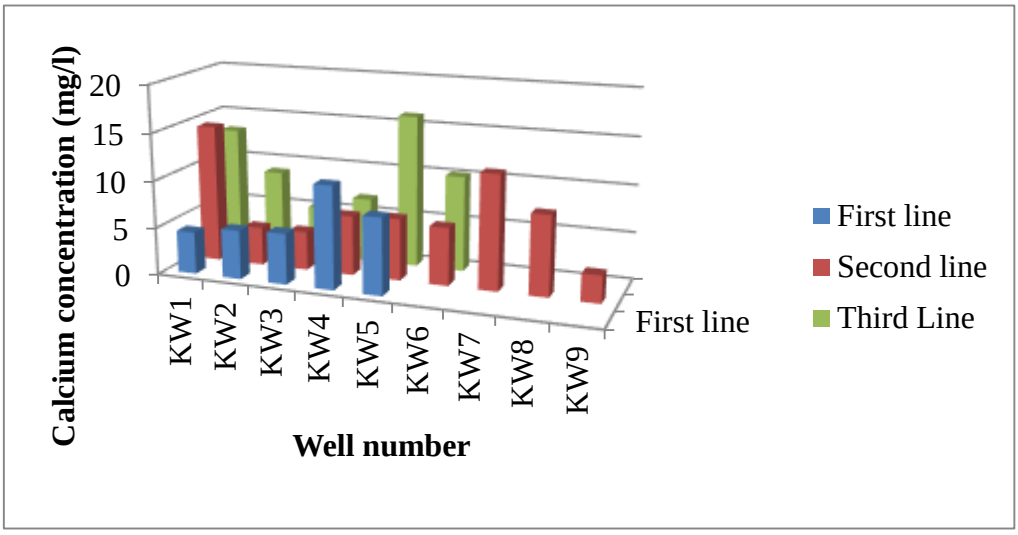

Figure 14: Variation of Calcium concentration in the wells during the wet season in the first aquifer of Kota Bharu

The average of SO4 was 11.46 mg/L during the dry season; the highest value was 33.81 mg/L in the well (4) at the village of Padang Kiat due to its location within the coastal area. The lowest value was 1.43 mg/L, in the well (8) at the village of Padang about 2000 m from the sea which is low; due to the climate condition Figure 15.

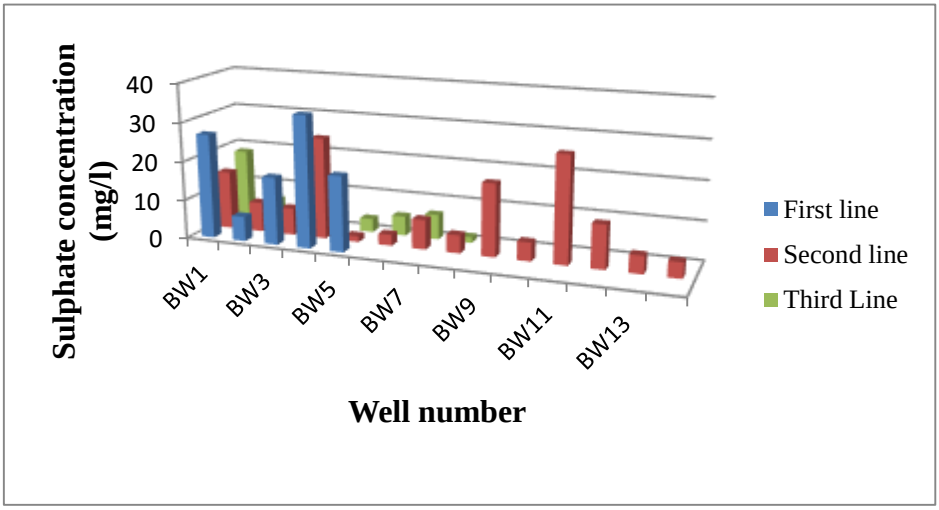

Figure 15: Variation of Sulphate concentration in the wells during the dry season in the first aquifer of Kota Bharu

However, during the wet season the SO4 average was 13.45 mg/L .The highest value was 35.22 mg/L, in the well (1) at the village of Cang Ching about 8000 m from the sea. The lowest value was 1.96 mg/L in the well (6) at the village of Tok Sadang about 2000 m from the sea which is shown in Figure 16

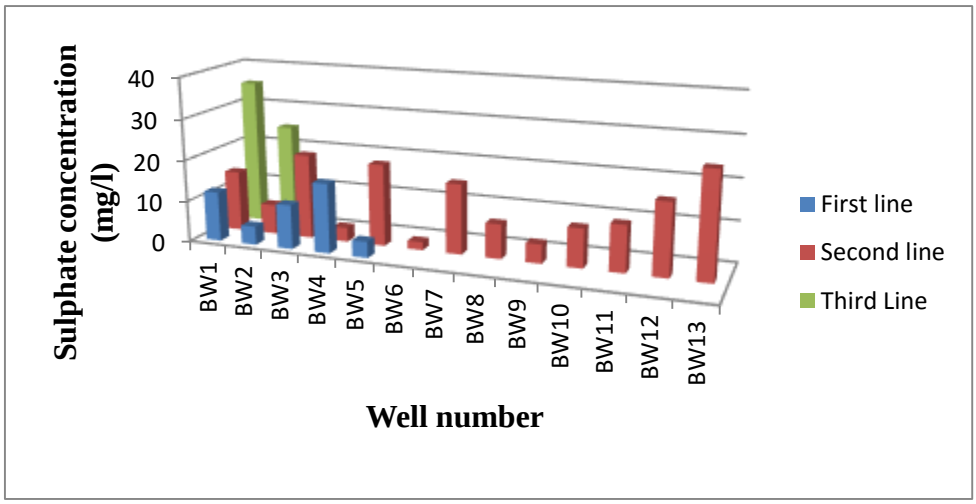

Figure 16: Variation of Sulphate concentration in the wells during the wet season in the first aquifer of Kota Bharu

The average of Cl was 35.71, the highest was 401.62 at well (1) in Dasar due to its location very close to the sea about 83 m. The lowest value was 4.05 mg/L in the well (5) at the village of Kemumin due to its location at about 2711m from the sea Figure 17.

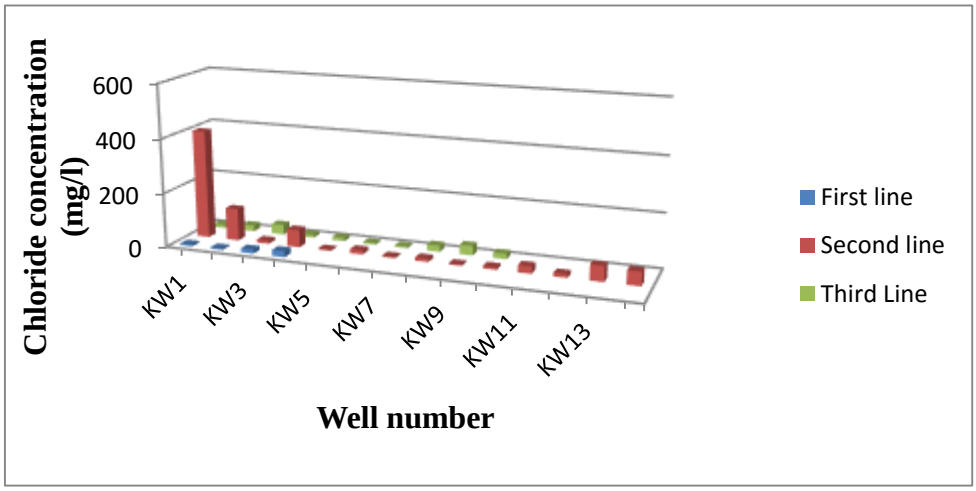

Figure 17: Variation of Chloride concentration in the wells during the dry season in the first aquifer of Kota Bharu

During the wet season the average of Cl was 39.89 mg/L the highest was 452.4 in the well (3) in Dasar due to its location very close to the sea about 83 m. The lowest value was 2.96 mg/L in the well (4) at the village of Kemumin due to its location at about 2711m from the sea Figure 18.

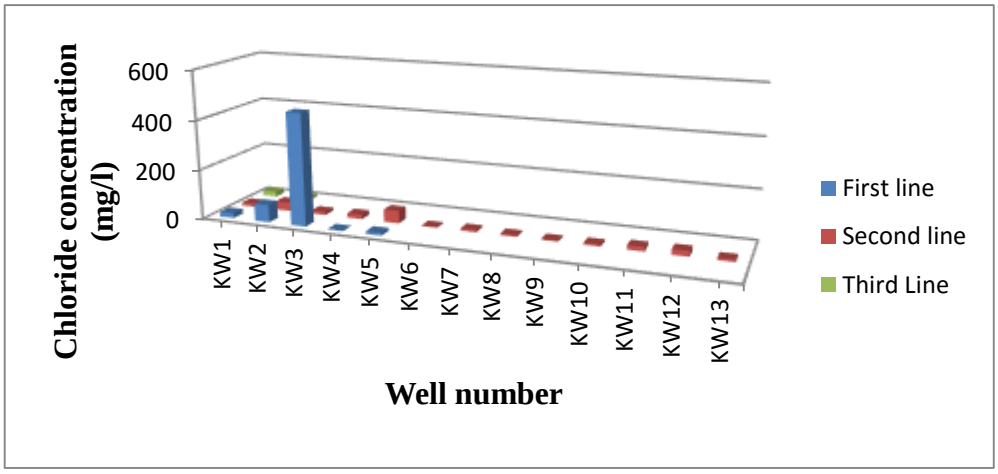

Figure 18: Variation of Chloride concentration in the wells during the wet season in the first aquifer of Kota Bharu

For the deep understanding to the salt water intrusion phenomenon, Special distribution system GIS application (Splain method) was used to clarify the variation of (EC&Cl) values among the area from the sea up to 10 kilometers. It became clear that during the dry season the values of electrical conductivity and chloride concentration increase near to the sea, and decrease gradually towards inland Figure (19, 20, 21&22). The saltwater/freshwater interface was located on the shoreline during the dry season. Through the wet season there was no impact of salt water intrusion because the heavy rainfall flushed the salt water from the first aquifer into the discharge area. However, the salt water was existed in the well (1) Figures (21&22) due to the casing condition, and not pumping the well water out.

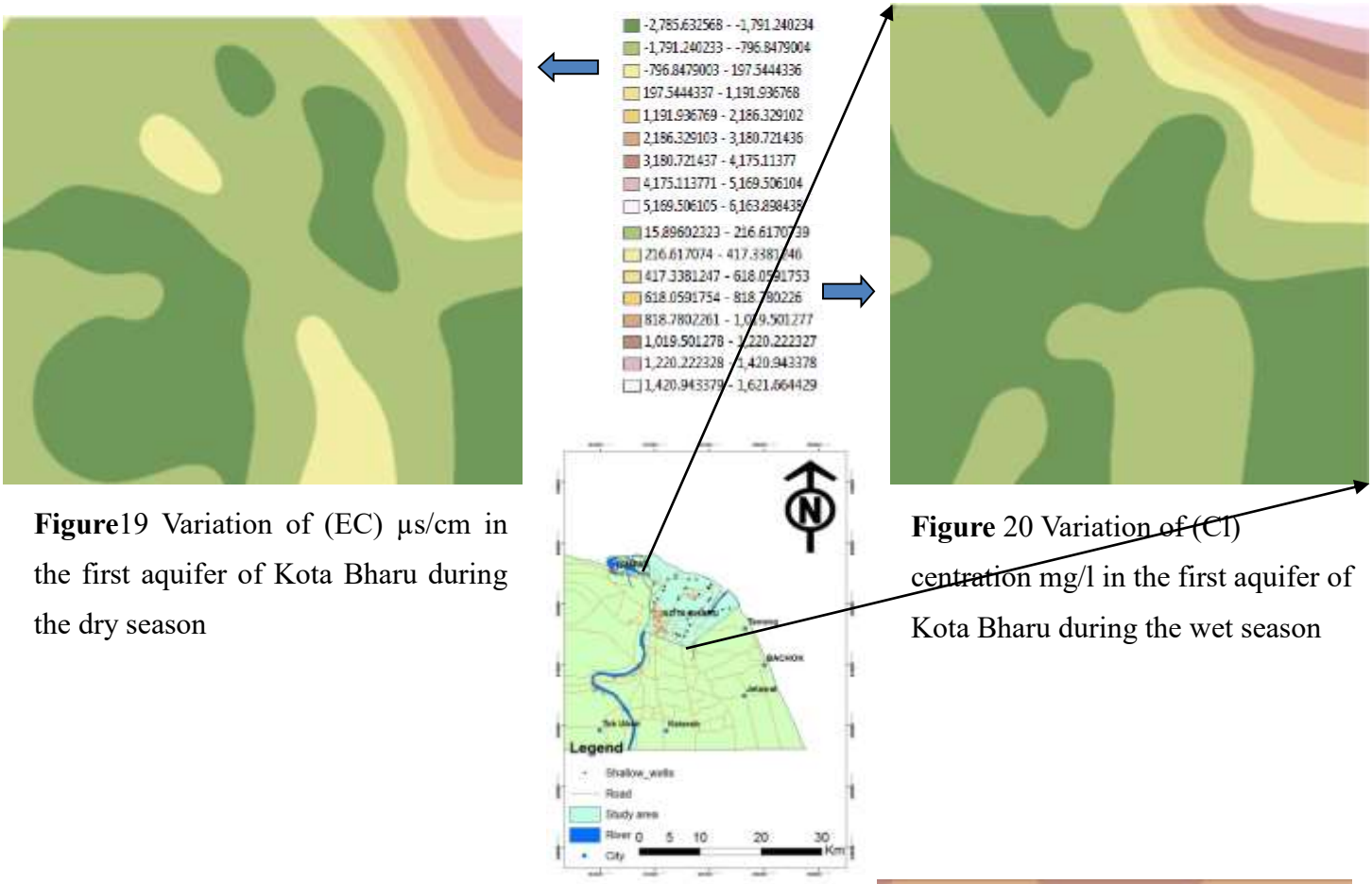

Figure19 Variation of (EC) µs/cm in the first aquifer of Kota Bharu during the dry season

Figure 20 Variation of (Cl) centration mg/l in the first aquifer of Kota Bharu during the wet season

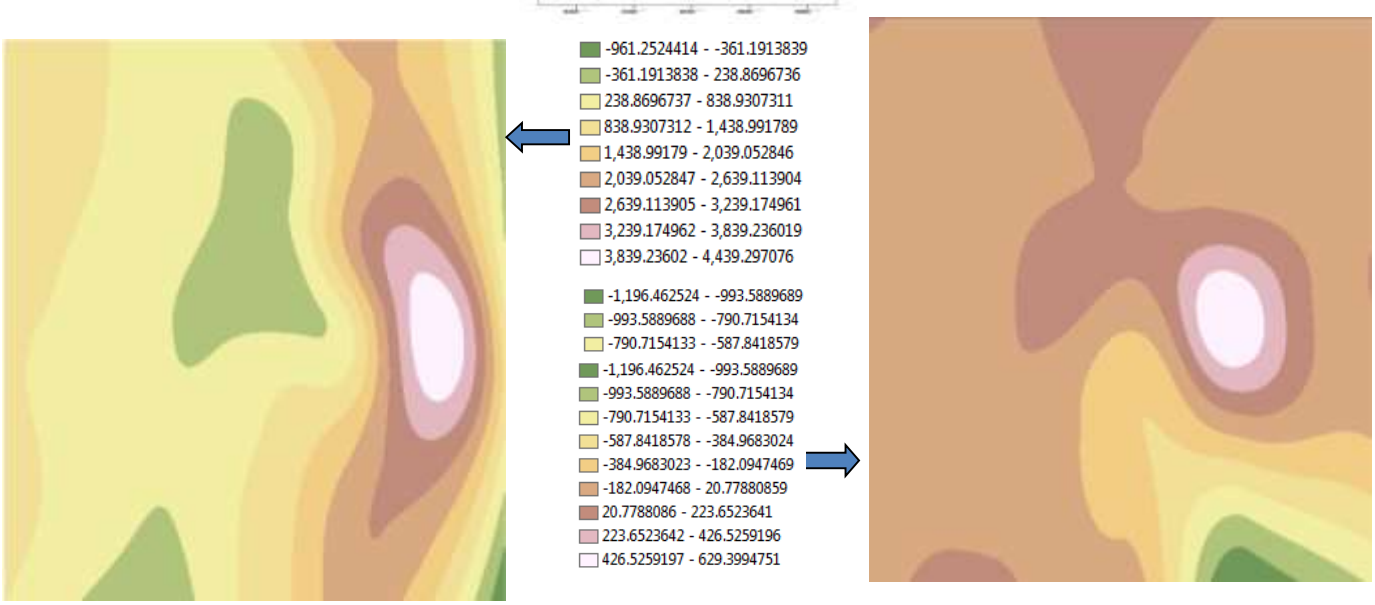

Figure 21 Variation of (EC) µs/cm in the first aquifer of Kota Bharu during the dry season

Figure 22 Variation of (Cl) concentration mg/l in the first aquifer of Kota Bharu during the wet season

4. CONCLUSION

In conclusion the ground water in the first aquifer is fresh except the well number (1). It is considered saline due to the high average of chloride, salinity, total dissolved solids, and electrical conductivity. This well (1) represents the salt water intrusion area (2.7%) of the total area. due to its location at the village of Dasar about 83 m from the sea, and due to the over extraction of ground water from this area especially during the dry season. Unreasonable land use considered as the main reason for the salt water intrusion in this area. There is no concern of sea water intrusion as far as the threats of sewage, contaminated rivers, and landfills. The freshwater / saltwater interface was located on the shoreline during the dry season and retreated under the seawater during the wet season. Therefore, it is recommended that the ground water from the well (1) needs treatment before consumption and continue in monitoring operation for the whole wells. In addition, reduce the pumping ratio of ground water from the salt water intrusion area; recharge the first aquifer from surface water which finally goes to the sea especially during the wet season. However, well siting, to avoid drilling in locations immediately adjacent to the coast prevent any future damages or high economic cost.

ACKNOWLEDGEMENT

The authors would like to record their appreciation to the Geology Department, University Kebangsaan Malaysia for assistance during fieldwork and in the preparation of this paper, in addition, special thanks to the Geological survey Department of Malaysia and Air Kelantan, to their assistance in collection of water samples from their monitoring wells, and the people in the study area. Atea K A Al Mabrok: Participated in the field work, lap work data analysis the writing of the manuscript and organized the study. Wan Zuhairi Wan Yaacob: Participated in the field work, reviewed the study and financial support. Abdulrahim Samsudin: Participated in the revision and editing of manuscript. Jasni Yaakub: Participated in the revision, editing of manuscript and financial support.

CONFLICT OF INTEREST

The authors would like to state that there is no conflict of interest related to the study.

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