Eph - International Journal Of Science And Engineering

ISSN (Online): 2454-2016
Volume 04 Issue 3 September 2018

DOI: https://doi.org/10.53555/eijse.v4i3.175

MAPPING OF SALT WATER INTRUSION DURING THE DRY AND WET SEASONS IN THE FIRST COASTAL AQUIFER OF TUMPAT KELANTAN, MALAYSIA

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Abstract:-

The most prominent threats to the main water resource in north east Kelantan, is the intrusion of salt water especially in the second aquifer and part of the third aquifer. The main purpose of this work was to evaluate the salt water intrusion into the first aquifer. It was investigated using physical and chemical characteristics of ground water, which revealed that. A range of pH from 4.95 7.63, electrical conductivity (EC) 70 −2561 µs/cm, salinity 0.02−1.21, and total dissolved solids 0.025−1.73 mg/l. A range of calcium (Ca), sodium (Na), chloride (Cl) and sulfate (SO_4) 1.51 −37.41, 2.11 −78.92, 2.84− 575.2 and 0.92 −172.82 mg/L respectively. The values of Na, Ca, SO_4, Cl and EC were decrease gradually from the sea towards inland and vice versa. A variation in ground water levels between the dry and wet seasons which were in the range of 0.2−1.97 m. Moreover, the freshwater/saltwater interface was located on the shoreline in the dry season and retreated in the wet season. Generally, the salt water intrusion was discovered in the first coastal aquifer; however, it has affected a small area. The ground water in this aquifer is fresh (except the three wells 11, 19 and 20) that considered as salty due to the high average of chloride, salinity, total dissolved solids, and electrical conductivity.

Keywords*: Salt water intrusion; First aquifer; Tumpat, Kelantan.*

I. INTRODUCTION

Salt water intrusion into the aquifer of fresh water is a communal environmental issue in many parts of the globe. It is often caused by natural conditions and human activities. The saline intrusion of aquifers might originate from various sources such as sea water, saline water in enclosed areas like a tidal lagoon; return flows to stream from disposal wells, and leakage from irrigated lands [1]. Ground water is the most vital natural resources. It delivers potable water supply to rural and urban populations, supports manufacturing and irrigation. In addition, it sustains the rivers flow and streams, preserves riparian and ecosystems of wetland [2]. Quality of ground water reservoir can be affected by some factors, such as contamination by salt water intrusion or by toxic industrial chemic waste. On the other hand, quality of surface water may be impacted via ground water flow or vice versa [3]. The amount of salt water that has intruded into the fresh water aquifer eventually mixes with the ground water and inevitably to production wells and finally our drinking water which is not suitable for human life and most of the animals and plant types. Therefore, both ground water and surface water are two vital and interconnected water bodies that relate to each other in terms of quality and quantity. However, either ground or surface water, the general goal is to make sure that, sufficient supplies of good quality of water are available to all societies, the ones living nowadays and for generations of future, while conserving required quality and quantity of water flow to sustain vital functions of ecosystems [4].

These contaminants represent communal environmental problems that have produced the need to find appropriate ways for monitoring the extent of such environmental damage [5],[6],[7]. The most important parameters for investigation of ground water are electrical conductivity (EC), total dissolved solids (DS), calcium (Ca2+), magnesium (Mg+), sodium (Na+) and chloride (Cl). The six parameters mentioned above affected the characteristics of ground water are an evidence of sea water intrusion [8].

Although the ground water represents about 90% of the whole water resources in Tumpat [9], with increasing population density, increased demand for water and the ground water has been suffering from some environmental problems such as salt water intrusion, pollution, and drought. The salt water intrusion is considered as the most concern in the study area. Hence, this paper aimed to mapping the salt water intrusion area and its changes during the dry and wet seasons using the physiochemical characteristics of ground water and GIS application.

II. Materials and methods

A. Location of the study area

The investigated area is situated on the northeast coast of Malaysia, located along the coastal area of northeast Kelantan. It extends about20 km in length and 10 km in width, between the boundaries of Thailand and the Kelantan River as shown in (Fig 1).

Fig.1. Boundaries of the study area

Source: Modified after [10].

Geological Condition

Quaternary Sediments cover most of the coastal area of Kelantan (Fig 2), whereas the bedrock is granite. It divided by short rivers and streams that flow towards the South China Sea. Moreover, the largest river of Kelantan drains the area and flow into northeast. The Pengkalan Datu River drains the plain in southeast, [9].

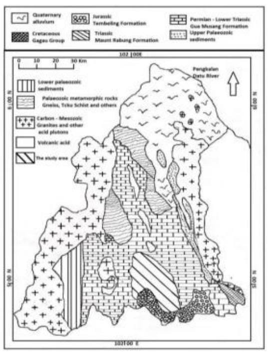

Fig.2. Geological map of Kelantan,

Source: Modified from [11]

B. Hydrogeological Condition

The quaternary sediments Fig 3 consist of alternating layers of sand, silt, gravel, and clay. The cross-section is showing that the sediments cover granite bedrock. The Quaternary sediments can be divided into four aquifers. The silty clay layers separate these aquifers from each other. The topmost ranged from a few meters to maximum 15 m under the ground, and separated from the second aquifer by a layer composed mainly of clay. The second aquifer's depth is generally between 20 - 35 m with a thickness about 15 m. Once again, a clay rich layer separates this aquifer from the third aquifer below it. The depth of the third aquifer is more than 40 m, and it also shows great thickness exceeding 50 m in some wells. The fourth aquifer is situated on the granite bedrock, which is not always detected [12].

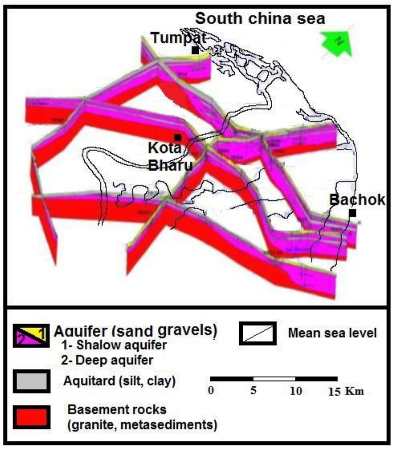

Fig.3 Cross section of Tumpat, Kelantan

Source: Modified from [12].

C. Water supply in Kelantan

A conventional ground water supply distribution project, came into existence when the Kota Bharu water works institute has been established, which is now under the administration of the Malaysian Public Works Department, in the late twenties [13]. The initial water resources study in the area of Kelantan was carried out by German consultants, in collaboration with the Geological Survey Department of Malaysia [14, 15&16] as cited in [17]. A local contractor, Binner and Partners (Malaysia) was awarded a contract to investigate the future water demand, and recommend the best means to meet the demand [18]. The public Waterworks Department usually takes ground water from the first and third aquifers. Ground water from the second aquifer is not utilized because it is brackish and not suitable for domestic use [17].

D. Physical and chemical data

Two types of surveys (physical and chemical) were carried out within the study area. It was divided into three parts (A, B, C) and three lines (first, second and third) as shown in Fig 4.

Fig.4.The physical and chemical survey lines in the study area.

Source: Modified from [10].

These parts and lines were created due to a large number of wells; in addition, to accurate determination to the salt water intrusion phenomenon during the dry and wet seasons. The hydro physical survey was conducted utilizing Water Quality meter (YSI). It was used to determine temperature (°C), electrical conductivity EC (μs/cm), total dissolved solid TDS (mg/L), and pH. Moreover, the ground water level and total depth of the wells were measured at the same time. For the chemical survey, twenty one ground water samples were collected during the dry and wet seasons from the shallow wells in different sites of Tumpat, and its surrounding areas. The chemical analysis was conducted to determine the concentration of calcium (Ca), sodium (Na), chloride (Cl) and sulfate (SO_4). It was using Ion Chromatography (IC) and

Inductively Coupled Plasma Mass Spectrometry ICP-MS Instruments. The quantitative data of Cl and EC were used to produce the salinity map utilizing (GIS) application.

II. Results and discussion

The results showed that, in the dry season, the level of ground water ranged from 0.2 – 2.5 m. While during the wet season the ground water level ranged from 0.55 – 1.97 m. The variation in ground water levels refers to the annually rainfall, geological and geomorphological condition, and ground water usage. The total depth of the wells, ranged from 1.52–15.5 m. The temperature values ranged from 7.92 29.24 °C. The electrical conductivity ranged from 70-2561 µs/cm, were the values of 70-400 µs/cm, represent the fresh ground water with a very low content of elements. While the values ranged from 401-1000 µs/cm represent the fresh ground water with maximum allowable of elements according to the Malaysian water quality standard. However, the values ranged from 1000-2561 µs/cm represent the salt water intrusion. The highest value 2561µs/cm was in the well (20), due to its location within the salt water intrusion area (C) area, in Kok Bedollah village, about 1653 m from the sea. Furthermore, the value of 1923 µs/cm in the well (19), in the (C) area at the same village Kok Bedollah are high due to the same reason Fig 5.

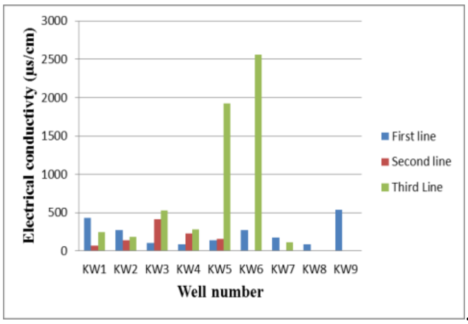

Fig.5. Variation of electrical conductivity in the wells during the dry season in the first aquifer of Tumpat

In contrast, during the wet season the (EC) values ranged from 90-540 µs/cm which were lower than it in the dry season and in the range of Malaysian drinking water standard, unlike what in the summer. This variation reflects the role of rainfall in reducing concentration of elements. Generally, the very low values and moderate reflect the local environmental impact and the high values reflect the salt water intrusion as shown in Fig 6& table 1.

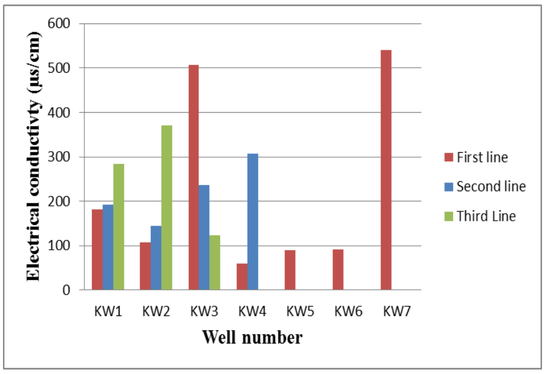

Fig.6. Variation of electrical conductivity in the wells during the wet season in the first aquifer of Tumpat

	Dry Season				Wet Season	
First line	Second line	Third Line	wells	First line	Second line	Third line
435	70	249	KW1	182	193	284
271	137	188	KW2	107	145	370
104	412	531	KW3	507	237	123
90	230	286	KW4	60	307	
141	155	1923	KW5	90		
276		2561	KW6	91		
173		118	KW7	540		
91			KW8			
540			KW9			

Table1.Variation of electrical conductivity in the wells during the dry and wet season in the first aquifer of Tumpat

On the other hand, the chloride concentration values ranged from 3.35-575.2 mg/L. The high value of 575.2 mg/L was a result of waste water intrusion into the well (11), due to its location very close to the waste water wells within the (B) area, in Nicang village, about 4666 m from the sea Fig 7.

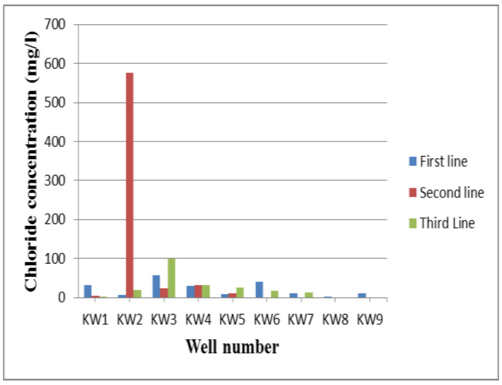

Fig.7. Variation of chloride concentration in the wells during the dry season in the first aquifer of Tumpat

Through the wet season, the average of chloride was in the range of 2.84-102.12 mg/L, which is very low compared to the dry season. It refers to the role of rain in reducing the concentration of elements as shown in Fig 8 &Table 2.

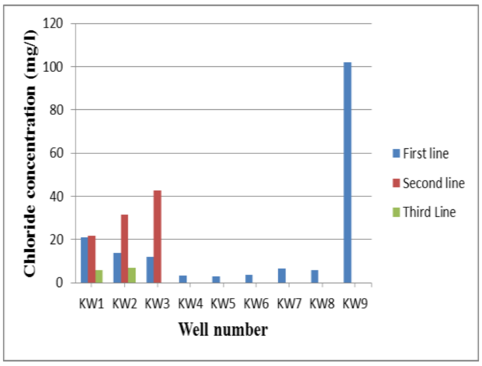

Fig. 8.Variation of chloride concentration in the wells during the wet season in the first aquifer of Tumpat

Dry season				Wet season		
First line	Second line	Third Line		First line	Second line	Third Line
32.73	4.1	3.52	KW1	20.998	21.79	6.008
7.15	575.2	19.48	KW2	13.795	31.46	6.92
57.28	23.11	99.05	KW3	12.12	42.71	
29.06	31.73	32.49	KW4	3.422		
9.03	11.59	25	KW5	2.84		
40.99		17	KW6	3.52		
10.05		13.67	KW7	6.62		
3.352			KW8	5.91		
11.005			KW9	102.12		

Table 2.Variation of chloride concentration in the wells during the dry and wet season in the first aquifer of Tumpat

The total dissolved solids values, ranged from 25-1730 mg/L during the dry season. The highest value (1730 mg/L) represents the salt water intrusion area. This intrusion refers to its location in the (C) coastal area at the village of Kokbedollah (1653 m) from the sea. For the second high value of 1538 it reflects the same reason that caused the highest value because both are in the same area. The lowest value was 25 mg/L due to its location in the (A) area, in the village of Pangang at a distance of about 6280 m from the sea. In contrast, to the wet season, the range of TDS was 0.06-0.33 mg/L, which is low due to the role of rain in reducing the concentration of elements as shown in Fig.9, Fig.10 and Table 3.

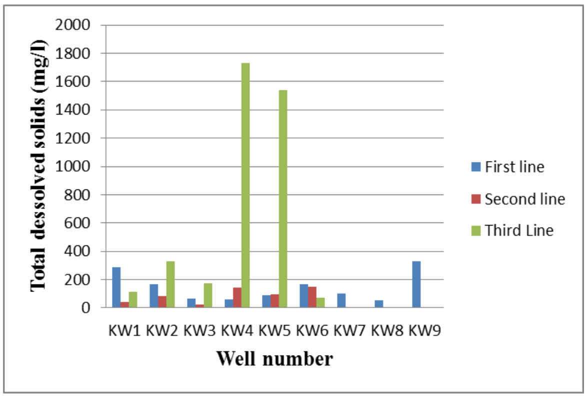

Fig.9.Variation of (TDS) concentration in the wells during the dry season in the first aquifer of Tumpat

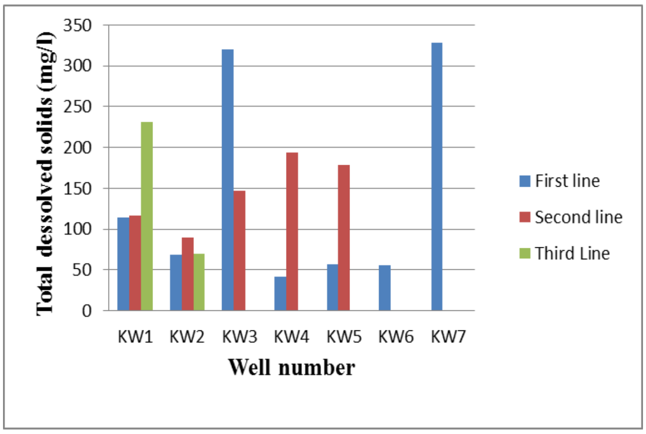

Fig. 10.Variation of (TDS) concentration in the wells during the wet season in the first aquifer of Tumpat

	Dray season			Wet season		
First line	Second line	Third Line		First line	Second line	Third Line
285	42	114	KW1	114	116	231
165	84	327	KW2	68	89	70
66	25	173	KW3	320	147	
61	143	1730	KW4	41	194	
87	97	1538	KW5	57	178	
168	152	72	KW6	56		
101			KW7	329		
56			KW8			
329			KW9			

Table3.Variation of (TDS) concentration in the wells during the dry and wet season in the first aquifer of Tumpat

The pH average, ranged from 4.95-7.63 during the dry season. The highest value (7.63) was in the (A) area, at the village of Palekbang about 8656 m from the sea. The lowest value was 4.95 in the (C) area in Kokbedollah village, about 1653 from the sea due to its location in a farming area which perhaps, affected by fertilization activities. During the wet season, the pH average ranged from 4.28-7.63. The highest value (7.63) reflects the influence of carbonate rocks; due to its location in the (A) residing area of Palekbang village, about 8656 m from the sea. The lowest value was 4.28 in the village of Kelaboran about 2212 m from the sea. Consequently, constant rainfall, release fertilizers from the soil into ground water through infiltration operation.

The average of Na ranged from 2.11-59.89 mg/L during the dry season. The highest value (59.89 mg/L) refers to its location in the (B) coastal area in Gelam Cecil village, about 4370 m from the sea. The lowest value was 2.11 mg/L due to its location in the (C) area at Geting village about 1480 m from the sea. In contrast to the wet season, the average of Na ranged from 2.67-78.92 mg/L. The highest value was 78.92 mg/L, in the (B) area at the village of Nicang at the distance of about 4666 m from the sea. The lowest value was (2.67 mg/L) in the well (7) within the (A) area at Jalbesar village at the distance of about 8139 m from the sea. The variation of sodium concentration depends on distance from the sea, amount of rainfall and ground water usage see Table 4

Dray season				Wet season		
First line	Second line	Third Line		First line	Second line	Third Line
56.77	59.89	8.95	KW1	16.42	8.42	6.49
8.75	21.18	8.36	KW2	7.55	15.58	6.48
10	10	10	KW3	5.78	28.25	
7.96	9	10.56	KW4	5.02		
2.84	2.77	8	KW5	2.67		
	11.99	4.18	KW6	3.36		
	1.51	6.27	KW7	4.13		
	5	9.41	KW8	6.9		
	6.81	12	KW9	78.92		
	7.5	15	KW10			
	10.07		KW11			

Table 4.Variation of Na concentration (mg/L) in the wells during the dry and wet season in the first aquifer of Tumpat

The average of Ca ranged from 1.51- 37.41 mg/L throughout the dry season. The highest value was 37.41 mg/L at the (C) coastal area in Kokbedollah village, about 1653 m from the sea. The lowest value was 1.51 mg/L at Palekbang village of about 8656 m from the sea. Whereas, the average of Ca during the wet season ranged from 1.76 -16.31 mg/L, the highest value of 74.92 mg/L. at the village of Kelaboran about 22212 m from the sea. The lowest value was 1.76 mg/L at the (A) residential area of Palebang distance of about 8656 m from the sea. The variation in Ca concentration average is attributed to the distance from the sea, rainfall, impact of the local rocks and soil, and water usage Table 5.

Dray season				Wet season		
First line	Second line	Third Line		First line	Second line	Third Line
14.8	5.04	3.45	KW1	6.37	16.32	4.96
13.9	6.39	4.11	KW2	3.89	9.91	7.87
18.52	2.13	8.97	KW3	13.40	13.88	9.64
11.95	7.71	10.12	KW4	1.77	10.72	
1.51		5.76	KW5	6.97	17.66	
5.34		8.94	KW6	8.80	6.96	
17.1		37.41	KW7	15.53		
8.1		3.76	KW8			
7.46			KW9			

Table 5.Variation of Ca concentration in the wells during the dry and wet season in the first aquifer of Tumpat

The average of SO4 ranged from 1.41-33.81 mg/L during the dry season. The highest value was 33.81 mg/L due to its location within the (B) farming area about 4370 m from the sea. The lowest value was 0.92 mg/L, which is low; due to its location in the (A) area in Pangang village about 6280 m from the sea. However, during the wet season the average ranged from 1.45- 29.83 mg/L .The highest value 29.83 mg/L in (B) area in Melintang village about 7447 m from the sea. While, the lowest value was 1.45 mg/L in (A) farming area in Jalbesar at the distance of about 8139 m from the sea which is shown in Fig11, Fig 12& Table 6.

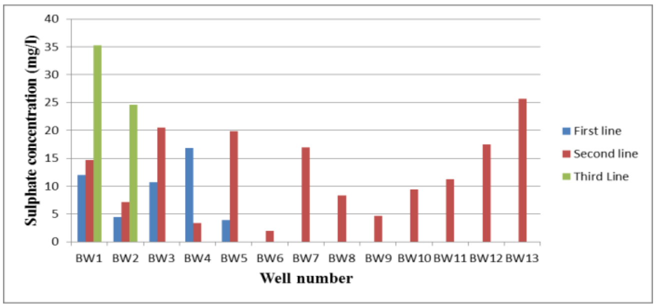

Fig.11. Variation of sulphate concentration in the wells during the dry season in the first aquifer of Tumpat

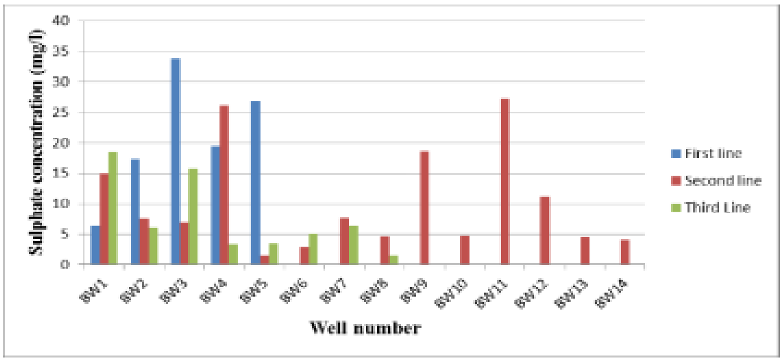

Fig.12. Variation of sulphate concentration in the wells during the wet season in the first aquifer of Tumpat

Dray season				Wet season		
First line	Second line	Third Line		First line	Second line	Third Line
14.8	5.04	3.45	KW1	6.37	16.32	4.96
13.9	6.39	4.11	KW2	3.89	9.91	7.87
18.52	2.13	8.97	KW3	13.40	13.88	9.64
11.95	7.71	10.12	KW4	1.77	10.72	
1.51		5.76	KW5	6.97	17.66	
5.34		8.94	KW6	8.80	6.96	
17.1		37.41	KW7	15.53		
8.1		3.76	KW8			
7.46			KW9			

Table 6.Variation of SO4 concentration in the wells during the dry and wet season in the first aquifer of Tumpat

To the best understanding to the salt water intrusion phenomenon, spatial distribution system of EC values, Cl concentration, and their seasonal variations have utilized to illustrate the salt water intrusion area. GIS application (splain method) used to produce the salinity map.

From Fig13 the distribution of EC values during the dry season, which clearly appears the salt water intrusion in the (B&C) areas. The salt water intrusion has advanced as far as 1653 m in the (C) area in Kok Bedollah village. In addition, it has advanced as far as 4666 m from the sea in the (B) area in Nitchang village. The saltwater/freshwater interface was located on the shoreline during the dry season and retreated towards the sea during the wet season; due to the heavy rainfall (Fig 14).

With comparison to the distribution of Cl concentration during the dry season, there is a correlation patterns similar to the described above, (EC values distribution system) were the salt water intruded during the dry season, and returned towards the sea during the wet season as shown in Figs 15&16 .

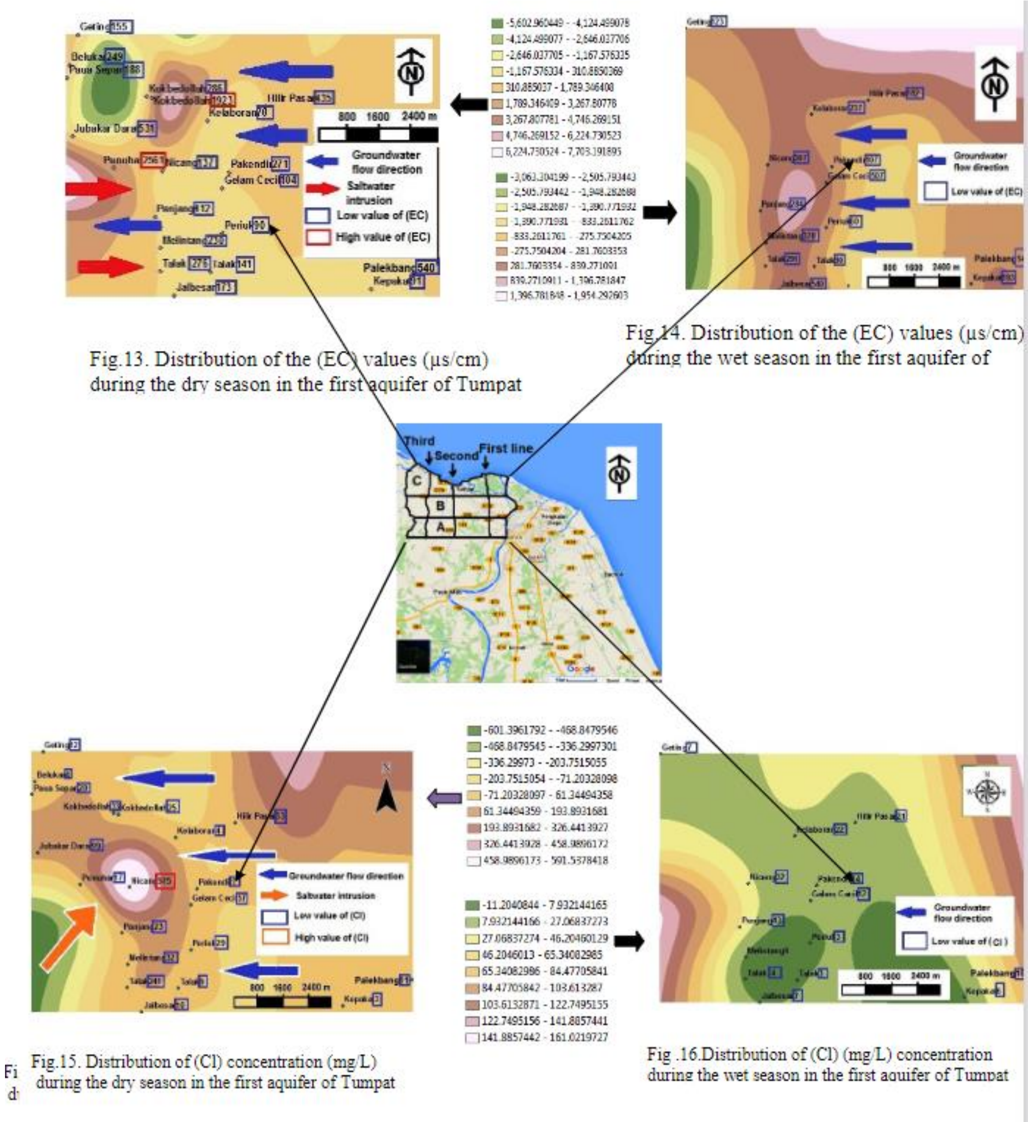

Fig.13. Distribution of the (EC) values (µs/cm) during the dry season in the first aquifer of Tumpat

Fig.14. Distribution of the (EC) values (µs/cm) during the wet season in the first aquifer of

Fig.15. Distribution of (Cl) concentration (mg/L) during the dry season in the first aquifer of Tumpat

Fig .16.Distribution of (Cl) (mg/L) concentration during the wet season in the first aquifer of Tumpat

The current study disagrees with [19], [12], [20], and [16] that, the first aquifer is fresh100%, and the fresh water/salt water interface is on the shoreline. However, the results of this study are similar to that obtained by [15]. A cording to the salinity map, the salt water had intruded as far as 3 km inland, and the minimum length of intrusion of the coast is 1km. However, analytical results of the chloride content of the first aquifer, in the said inferred zone in April 1977 did not support that, saline water has intruded as far inland, for about 1 km only as shown in Fig.17

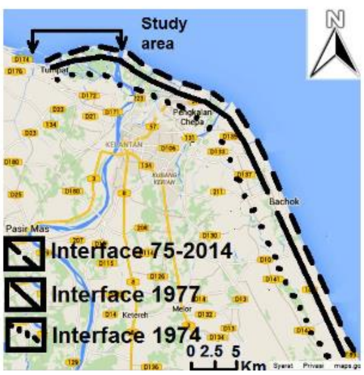

Fig.17. Variation of freshwater/saltwater interface on the first coastal aquifer of Tumpat, Kelantan during the period from (1974-2014) Source: Updated after [2].

Moreover, the actual saline zone seems to be in much smaller zone with a maximum intrusion length of about 1.35 km inland. The position of this boundary is not static. It varies with the seasons. During the Northeast Monsoon season, the boundary is being pushed outwards nearer to the sea. It is attributed to the greater available amount of fresh water, and a higher hydraulic gradient induced by the high rainfall, which replenishes the aquifer resulting in a greater pressure, exerted on the interface by the fresh water. The saline water is then slowly being flushed out towards the sea [13]. Finally this study provides an accurate determination to the salt water intrusion area, which was not given by the privies studies. The study has evaluated the salt water intrusion area as small as just about 14.29 % of the total study area. Thereby, the ground water from the first aquifer considered as fresh water.

III. Conclusion

The intrusion of salt water was detected in small area, which represented in the three wells (19 and 20) in the villages of Kok bedoallah about 4666 m from the sea and (11) in Nicang about 1653 m respectively. Unreasonable land use is considered as the permanent reason for the intrusion of salt water 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. In general, the ground water in the first aquifer is fresh (except the three wells 11, 19&20) that revealed a high average of electric conductivity, chloride concentration, total dissolved solids, Na, Ca, and SO4, which exceeded the World Health Organization [21]. Therefore, it is recommended that the ground water from the three wells (11,19&20) need to treat before consumption and continue in monitoring operation for the whole wells and update the salinity map annually. 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.

Acknowledgments

The authors would like to record their appreciation to the Geology Program, University Kebangsaan Malaysia for assistance during the fieldwork and in the preparation of this paper. In addition, special thanks to the Geological survey Department of Malaysia and Air Kelantan for their assistance in the collection of water samples from their monitoring wells, as well as the people in the study area.

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