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Temporal and Spatial Variation of Tuberculosis Incidence in Iraq Using Geographic Information Systems

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Abstract

The results reveal a temporal variation in tuberculosis incidence in Iraq during the period 2014–2022, showing an overall increasing trend in reported cases across most governorates. Spatially, the highest incidence rates were concentrated in Basra, Baghdad, and Wasit governorates compared with other regions, indicating a clear geographic disparity in disease distribution. The findings also indicate that males were more affected than females throughout most of the study period. In addition, a positive relationship between age and tuberculosis incidence was observed, with infection rates increasing with advancing age in both sexes. At the detailed age-group level, the highest number of male cases was recorded in the 20–44 years age group, whereas females showed higher incidence in the 1–19 and 45–64 years age groups. Overall, the study demonstrates a pronounced spatial and temporal heterogeneity in the distribution of tuberculosis in Iraq, reflecting uneven patterns of disease occurrence across governorates and population groups.

Keywords: Geospatial database, GIS, Spatial variation, Sustainable development, Tuberculosis

التباين الزماني والمكاني لانتشار مرض السل في العراق باستخدام نظم المعلومات الجغرافية

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الملخص

تُظهر النتائج وجود تباين زماني في معدلات الإصابة بمرض التدرن في العراق خلال المدة 2014–2022، مع اتجاه عام نحو الزيادة في عدد الحالات المسجلة عبر معظم المحافظات. وعلى المستوى المكاني، تركزت أعلى معدلات الإصابة في محافظات البصرة وبغداد وواسط مقارنة ببقية المحافظات، مما يعكس تباينًا جغرافيًا واضحًا في انتشار المرض. كما بينت النتائج أن الذكور كانوا الأكثر إصابة مقارنة بالإناث في معظم سنوات الدراسة. وأظهرت التحليلات ارتباطًا طرديًا بين العمر ومعدلات الإصابة، حيث تزداد الحالات مع التقدم بالعمر لدى كلا الجنسين. وفيما يتعلق بالتوزيع العمري التفصيلي، سُجلت أعلى الإصابات لدى الذكور ضمن الفئة العمرية (20–44 سنة)، في حين أظهرت الإناث معدلات أعلى في الفئتين (1–19) و(45–64) سنة. وتؤكد النتائج وجود تباين مكاني وزماني واضح في انتشار مرض التدرن داخل العراق، مع اختلافات ملحوظة بين المحافظات والفئات السكانية، مما يعكس نمطًا غير متجانس لتوزيع المرض.

الكلمة المفتاحية: قاعدة البيانات الجغرافية المكانية، نظم المعلومات الجغرافية، التباين المكاني، التنمية المستدامة، السل

1. Introduction

Infectious diseases, especially tuberculosis (TB), are one of the most important global health challenges affecting millions of people every year [1]. Tuberculosis (TB): Tuberculosis is a contagious infectious disease that causes death [2], which affects the respiratory system and is transmitted from an infected person to a healthy person through air contaminated by coughing, sneezing, or contact with infected people [3]. It often affects the lungs, but other parts of the body are also exposed to the bacteria, such as the spine, kidneys, and brain [4]. This infectious disease is caused by the bacterium (Mycobacterium tuberculosis) [5], and it comes second after HIV/AIDS in causing a high mortality rate [6].

Despite significant progress in controlling this disease in many countries, TB remains a public health threat in many countries, including Iraq [7]. In the past decade, Iraq has seen a significant decrease in its TB incidence rate, dropping from 45 to 23 cases per 100,000 people [8 9]. This achievement has placed Iraq in the ranks of low TB burden countries, reflecting the effectiveness of its national strategies in combating this disease [10]. However, combating TB requires careful analysis of the spatial and temporal patterns of its spread to direct health resources and actions more effectively [11].

Several local and global studies were conducted to investigate TB's spatial distribution and epidemiological patterns [7] [12] and [13]. A previous study regarding lung cancer and tuberculosis mortality in Basra from 2014 to 2019 stated that TB-related deaths have seasonal and spatial variations, with higher concentrations in urban areas [14]. Another research concerning TB prevalence in Najaf highlighted significant spatial disparities in infection rates (specifically between rural and urban populations) [5]. Also, the 2024 Global Tuberculosis Report by the World Health Organization (WHO) illustrated the resurgence of TB as a leading infectious disease [10]. Therefore, improved screening and intervention methods need to be applied.

Furthermore, research on the spatial distribution of TB in Karbala inspected the prevalence of Mycobacterium tuberculosis genes, and the results have demonstrated genetic variations influencing TB spread [15]. Another study on economically inactive populations in Iraq suggested that socio-economic elements contribute to disease prevalence, as increased TB cases are directly proportional to higher unemployment rates [16]. In addition, a WHO report on global TB strategies indicated the significance of early detection and policy-driven interventions to mitigate the disease burden [17]. Lastly, a TB distribution analysis in Iraq's rural and urban environments reinforced the influence of environmental and demographic factors on TB incidence [10].

The use of geographic information systems (GIS) techniques in studying the distribution of the disease is important, as these techniques provide a powerful tool for analyzing epidemiological data and understanding the factors influencing the spread of tuberculosis. Many researchers point out that spatial analysis using GIS contributes to identifying high-risk areas, identifying patterns associated with infection rates, and improving health system response [18] and [19]. For example, a study in Karbala governorate showed the use of GIS to analyze the spatial distribution of chronic diseases, which contributed to identifying the most affected areas and directing health efforts towards them

[20]. Similarly, a study in Najaf governorate showed the spatial variation of tuberculosis incidence. This highlights the importance of spatial analysis in understanding the dynamics of disease spread [21]. By applying these techniques, researchers can assess the factors influencing the geographical distribution of the disease and identify temporal patterns that contribute to understanding how cases change over time.

This study aims to analyze the spatial and temporal distribution of tuberculosis (TB) cases in Iraq during the period 2014–2022 and to identify the governorates and demographic groups most affected by the disease using Geographic Information Systems (GIS). A geospatial database was developed using ArcGIS 10.8 to produce thematic maps illustrating disease distribution patterns. The study also examines variations according to gender and age structure in order to provide a comprehensive understanding of the spatial and demographic characteristics of TB incidence in Iraq., identifying the most affected governorates and knowing the distribution of the phenomenon by gender and age structure, and what is the reality of the spatial and demographic variation of those infected with this disease during the period 2014-2022.

2. Research Methodology

The study employed a descriptive approach to examine the phenomenon and collect official statistical data, while an analytical approach was applied to assess spatial variation using GIS techniques and geostatistical analysis. ArcGIS 10.8 was utilized to develop the geospatial database and generate thematic distribution maps.

2.1.The study area

The spatial boundaries of the search for the State of Iraq, which includes the governorates of Iraq, except for the Kurdistan provinces (Dohuk, Erbil, Sulaymaniyah), the area of Iraq (435052) km2, as it is astronomically located between two circles of (latitude˚37-¯27 _ ˚29-¯6 ˚) in the north and two longitudes (lines 48, ¯ 36 _ 38, ¯49) in the east, Iraq is located in the southwestern part of the Asian continent, as for the relative location of Iraq, it is bordered on the north by Turkey, on the south by Kuwait and Saudi Arabia, on the east by Iran, and the west by Syria and the Hashemite Kingdom of Jordan [20]. The total area of the study area is (395478) km2 distributed among the fifteen administrative units, and the period for the studied area is during the year 2022, and a comparison between the number of injuries for the years 2014 and 2022.

2.2.Early detection of tuberculosis:

The disease can be detected and diagnosed through chest X-rays, taking a sample of sputum and culturing it in sputum cultures, Tuberculin skin test, DNA amplification, and Polymerase Chain Reaction (PCR) [21].

2.3.Temporal variation in the incidence of tuberculosis (TB) in Iraq

Table 1 shows the temporal variation in the number of TB patients between 2014 and 2022. Table 1 presents the distribution of tuberculosis cases in Iraq between 2014 and 2022 and reveals substantial temporal and spatial variations in disease incidence across governorates. The increase in reported cases in 2022 compared with 2014 may reflect improvements in case detection, surveillance systems, and healthcare coverage, reflecting a shift in the pattern and prevalence of the disease over the years. The number of infected people overall increased in 2022 compared to 2014, which may be a result of

improved early detection of cases and the expansion of the healthcare network. This increase shows that despite the challenges, Iraq has made progress in monitoring and detection of the disease, which increases the accuracy of the data and reflects a greater prevalence of the disease in some areas. The data can be represented in Figs. 1 and 2.

Table:1 spatial distribution of tuberculosis patients 2014-2022.

S/N	Governorates	Male	Female	Total 2014	Male	Female	Total 2022
1	*Baghdad*	1158	1214	2372	1346	528	1874
2	*Basra*	276	357	633	1790	1482	3272
3	*Nineveh*	85	75	160	86	63	149
4	*Maysan*	103	138	241	52	77	129
5	*Diwaniyah*	205	185	390	53	42	95
6	*Diyala*	227	226	453	56	79	135
7	*Anbar*	49	41	90	144	120	264
8	*Babylon*	238	270	508	150	133	283
9	*Karbala*	154	177	331	143	103	246
10	*Kirkuk*	201	215	416	78	82	160
11	*Wasit*	191	266	457	318	146	464
12	*Dhi Qar*	320	329	649	54	44	98
13	*Muthanna*	100	123	223	14	27	41
14	*Salahuddin*	74	81	155	213	195	408
15	*Najaf*	118	148	266	32	28	60
16	*Total*	3499	3845	7344	4529	3149	7678

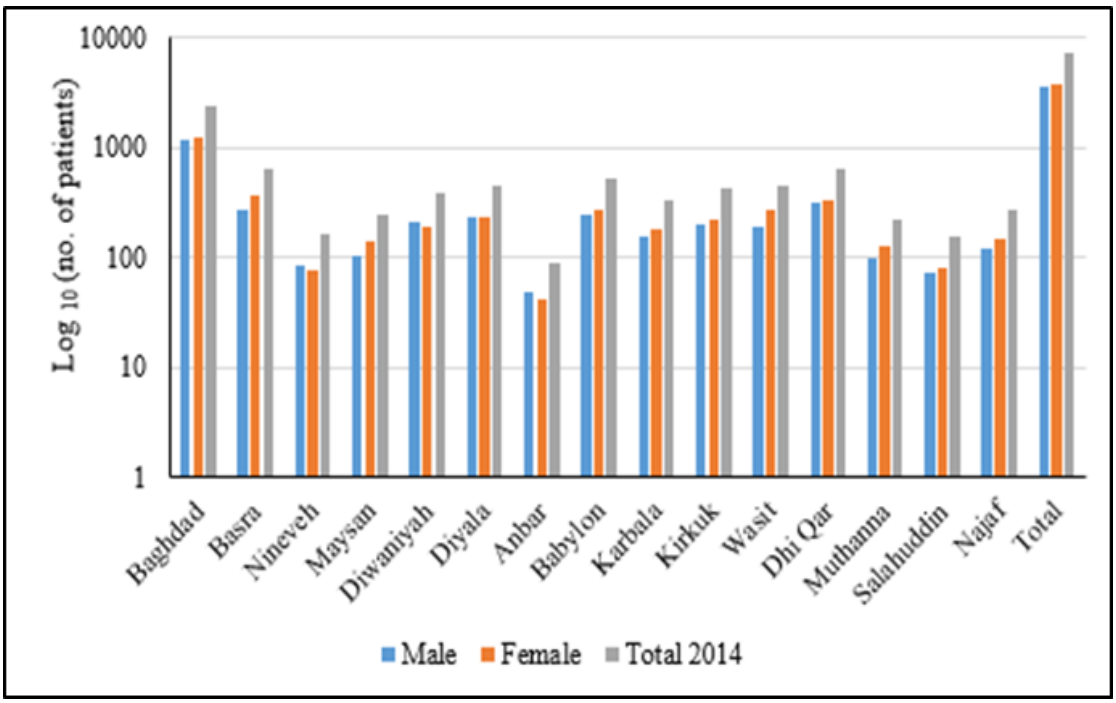

Fig. 1 The number of males and females infected with tuberculosis in 2014.

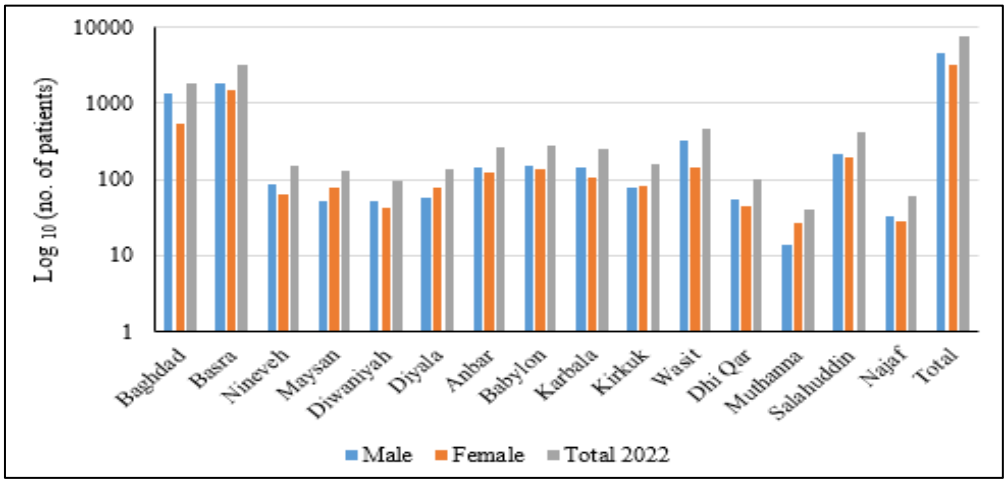

Fig. 2 The number of males and females infected with tuberculosis in 2022.

Spatially, Basra governorate shows a high density of cases, seeing a jump from 633 cases in 2014 to 3,272 cases in 2022. This may be related to increased population density or environmental and social conditions that contribute to the spread of the disease. On the other hand, although Baghdad saw an increase in the number of cases, the rate of increase was lower compared to Basra, which may indicate the effectiveness of detection and treatment strategies in the capital. The data also indicate a disparity in the distribution of cases between males and females, with males generally showing a higher incidence than females in most governorates. This may be a result of different social behaviors between the sexes or gaps in access to healthcare.

However, in some cases, female infections are increasing, as seen in some areas, indicating the need for more focus on prevention and treatment. The distribution of cases across governorates highlights the need for regionally targeted health strategies. For example, areas with high infection rates, such as Basra and Anbar, require greater health investments and improved prevention and diagnostic programs. In contrast, some areas that show fewer cases may need to strengthen awareness and early diagnosis programs to prevent outbreaks. The spatial and temporal distribution of tuberculosis in Iraq reflects the importance of using geographic information systems (GIS) in analyzing patterns of disease spread. It also indicates the need to better allocate health resources and enhance cooperation between health institutions to ensure effective control of the disease and minimize its impact on society.

2.4.The spatial distribution of pulmonary tuberculosis for all administrative governorates of Iraq.

Table 1 indicates the spatial distribution of the population infected with tuberculosis in Iraq, as shown in the map in Fig. 3, which was prepared in the ARC GIS 10.8 program, and the preparation of a database through geographical maps and temporal and spatial distributions, which are important in understanding spatial patterns to determine health interventions [12]. We show that there is a variation in the number of infected people through the color gradient for each governorate, where it turns out that the total number of people infected with tuberculosis throughout Iraq except the Kurdistan Region (7678) infected for the year 2022, and the highest incidence of the population in Basra Governorate (3272), which is about half the number of infected people in Iraq, and this is a large number recorded by Basra Governorate, This may be associated with environmental, social,

and economic factors that contribute to the spread of tuberculosis in Basra Governorate., where infectious diseases increase in conflict environments as a result of wars, deteriorating nutrition and unhealthy conditions such as air pollution resulting from oil extraction and burning gases and refinery waste that pollute the environment [22], social factors, which represent overpopulation, and economic factors represented by poverty [23] and a low level of education (illiteracy) [24] and environmental factors such as high temperatures that enhance the activity of bacteria and improve their viability [24], followed by Baghdad Governorate with the number of infected (1874) as a result of climatic conditions and environmental pollution resulting from the increasing population density and traffic [25], and the environmental pollution of the Dora refinery and its toxic gases are harmful to the health of individuals, followed in third place by Wasit Governorate with 464 infected, and Salahuddin Governorate is close to Wasit Governorate in the number of infected (408).

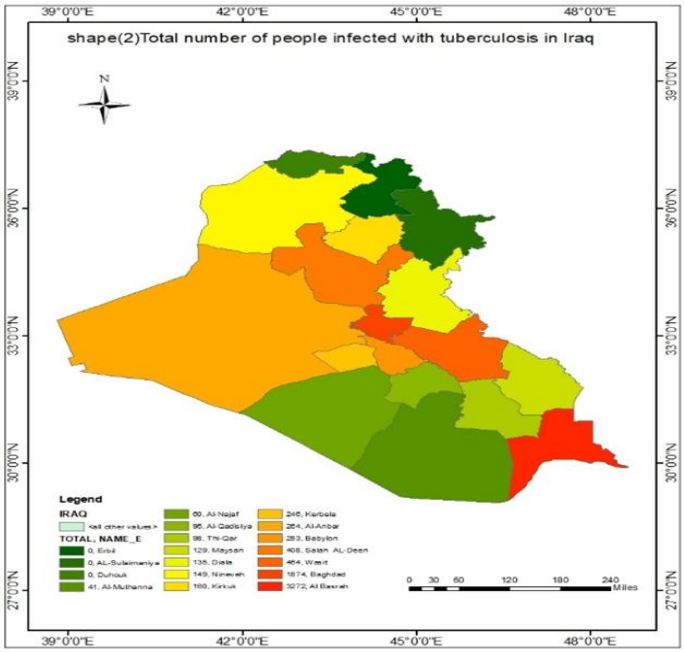

Fig. 3 Map displays the spatial distribution of the Iraqi population infected with tuberculosis using the ARC GIS 10.8 program and relying on Table 1.

Spatial variation of TB patients according to gender composition Table (1) indicates that the most infected with tuberculosis by gender are males, and the total number of infected people at the level of Iraq (is 4529), while the number of females reached (3149) infected, and these infections occur because males are more exposed to environmental pollutants because their work is outside the home, as well as smoking [26], as well as the amounts of gases emitted from vehicle exhaust during traffic [27], at the governorate level, Basra governorate came with the highest value at the gender level, as the number of infected males (1790) and the average number of cases (223.75) and the number of females (1482) infected and the average number of cases (185.25), followed by Baghdad governorate, the number of males (1346) infected and the average number of cases (168.25) and the number of females (528) infected and the average number of cases (66). (25) and the number of females (528) infected and the average number of cases (66), that is, the percentage of males infected is higher than the percentage of infected females, and the lowest incidence rate for the male and female's category was for Muthanna Governorate, where it amounted to (14) infected males and the average number of cases (1.75) and for females (27) infected and the number of cases (3.375). The map in Figure 4 also shows the spatial distribution of male and female patients with tuberculosis.

Table2 : Spatial distribution of TB patients according to age groups

Governorate	Less than a year		1-4		9-5		14-10		19-15		44-20		64-45		65 and above		Total		
	Male	female	Male	Female	Male	Female	Male	female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Total
Baghdad	0	0	18	2	4	1	3	11	9	10	60	90	55	28	8	5	157	147	304
Basra	1	1	4	11	3	6	9	35	109	103	317	263	184	189	70	41	679	649	1346
Nineveh	0	0	0	0	0	0	8	10	11	13	15	17	15	11	19	17	68	68	136
Maysan	0	0	2	1	5	1	0	2	2	1	23	20	9	14	5	7	46	46	92
Diwaniyah	0	0	0	1	2	0	2	0	3	3	11	23	7	6	5	2	30	35	65
Diyala	0	0	0	0	2	3	0	2	1	0	12	8	8	16	7	3	30	32	62
Anbar	3	0	67	136	2	31	44	22	88	99	135	56	20	5	5	2	364	351	715
Babil	7	5	10	5	4	10	5	10	7	20	41	68	14	47	12	22	100	187	287
Karbala	1	4	6	2	1	0	3	2	5	4	27	21	8	13	3	7	54	53	107
Kirkuk	1	0	0	0	1	3	2	0	1	3	22	47	12	39	8	12	47	104	151
Wasit	0	0	2	0	6	4	0	2	2	4	14	10	19	8	30	14	73	42	115
Dhi Qar	0	1	14	1	4	0	0	0	0	3	7	10	6	2	0	0	31	17	48
Muthanna	0	0	2	1	4	1	3	2	3	4	12	14	6	12	4	6	34	40	74
Salahuddin	0	0	0	0	0	0	1	0	0	1	5	9	9	2	1	3	16	15	31
Najaf	5	1	2	1	5	0	0	4	9	0	16	33	7	15	4	3	48	57	105
Total	18	12	127	161	43	60	80	102	250	268	717	689	379	407	181	144	1795	1843	3638

Source: Researchers' work using Ministry of Health data, unpublished data for 2022

3. Results

3.1.Variation between the age groups of those infected with tuberculosis

There is a relationship between the gender composition of the population and the emergence of this disease, so some diseases appear and spread in one gender without another, and this may be due to the physical structure in physiological factors that affect disease resistance and social and environmental factors that affect the chances of infection with pathogens, carriers, or reservoirs, Table 2. The data will be interpreted into several age groups to provide a deeper understanding of the distribution and relationships between the data. It was divided into several nine age groups, and spatial distribution maps were prepared for each age group.

3.1.1. Less than a year old

The total number of infections (30), the number of males (18) and females (12), the number of infections appears very low for both males and females in this age group, and the highest incidence is in Babil Governorate (12) infections, followed by Karbala Governorate (5) and Najaf (6), as shown in the map in Fig. 4.

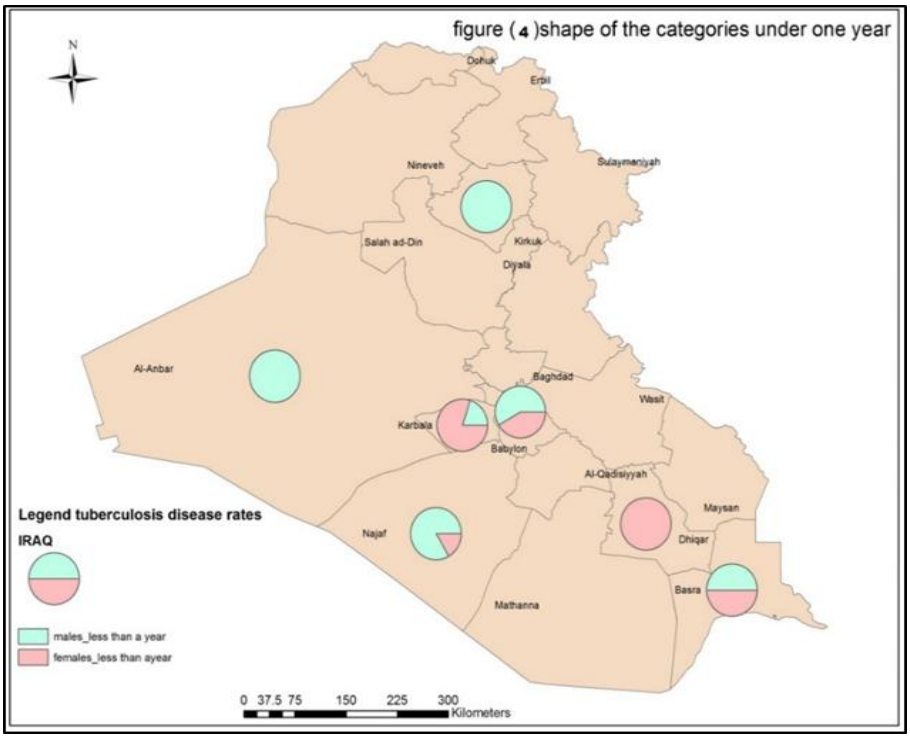

Fig. 4 Spatial distribution for the (under one year) category using the ARG GIS 10.8 program and relying on Table 2.

3.1.2. 1-4 years

The total number of tuberculosis cases in the study amounted to 288 cases, including 127 cases among males and 161 cases among females, which reflects a significant increase in the number of cases among females compared to males in this age group. The data also shows that the highest infection rate was among females compared to males. As for the geographical distribution of cases, Anbar governorate is the most affected with 203 cases, followed by Baghdad governorate with 20 cases. The governorates of Basra, Babylon, and Dhi Qar recorded 15 cases in each of them, as shown in Fig. 5.

3.1.3. 5-9 years

The number of tuberculosis cases increases significantly with age, with a larger gap between males and females in this age group. The total number of infected cases in this category amounted to 103 cases, of which 43 cases were among males and 60 cases among females, which indicates an increase in the number of infected females compared to males. In terms of geographical distribution, Anbar governorate recorded the highest infection rate with 33 cases, followed by Babil governorate with 14 cases, and Basra governorate with 9 cases, as shown in Fig. 6.

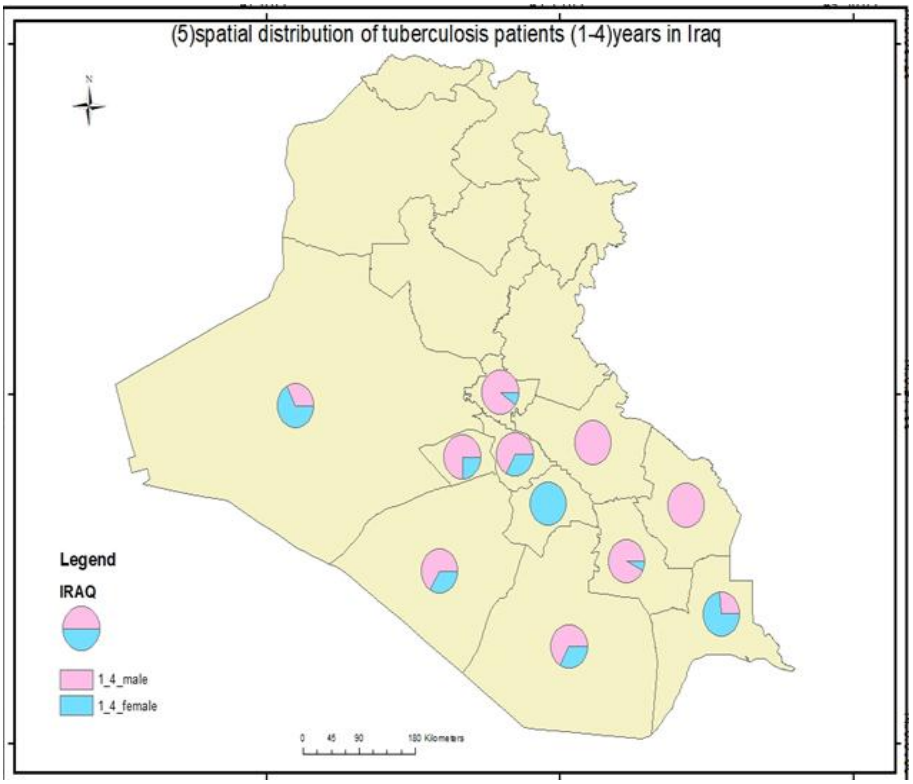

Fig. 5 Spatial distribution of (1-4 years) category using ARG GIS 10.8 program and relying on Table 2.

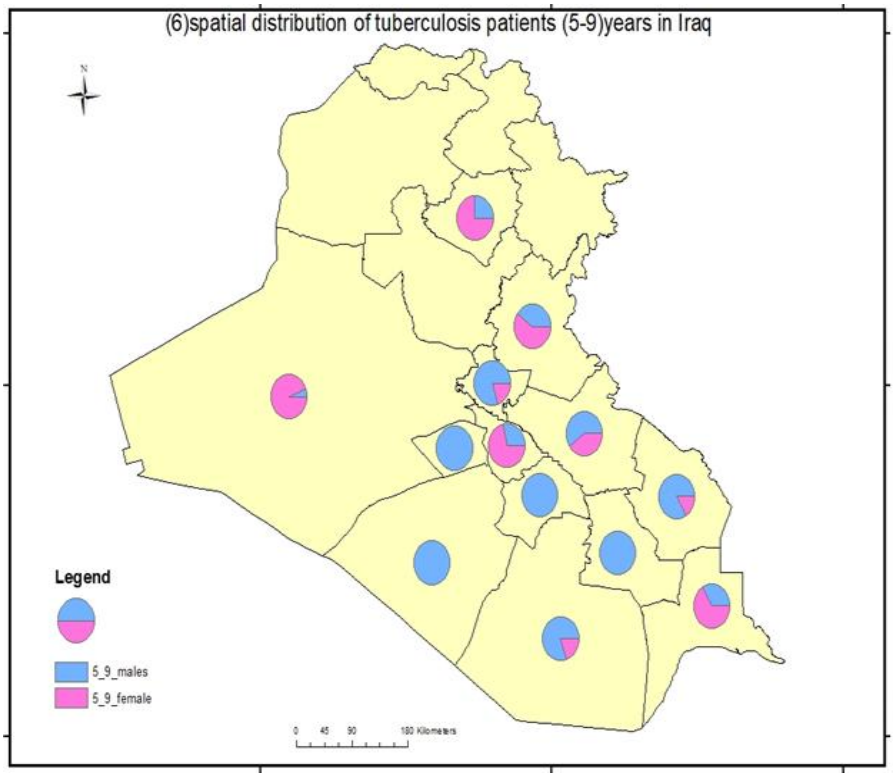

Fig. 6 Spatial distribution of the (5-9 years) category using the ARG GIS 10.8 program and relying on Table 2.

3.1.4. 10-14 years

The number of cases of tuberculosis among males and females continues to rise, with the gender gap persisting. The total number of infections in this category reached 182 cases, of which 80 were cases among males and 102 cases among females, reflecting a significant increase in the number of infections among females compared to males. In terms of geographical distribution, Anbar governorate recorded the highest infection rate with 66 cases, followed by Basra governorate with 44 cases, and Nineveh governorate with 18 cases, as shown in Fig. 7.

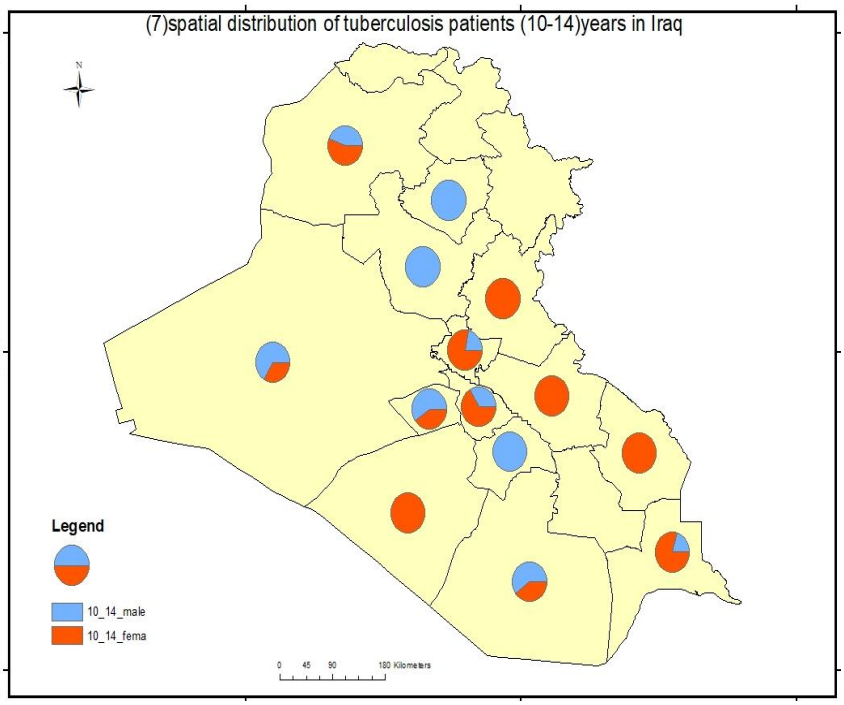

Fig. 7 Spatial distribution of (10-14 years) category using ARG GIS10.8 program and relying on Table 2.

3.1.5. 15-19 years

There is a larger gap between males and females in this age group, with females recording the highest number of injuries compared to males. The total number of infections in this category reached 518 cases, and it is noted that school students are the most vulnerable age group to tuberculosis (source). The number of infections among males (250) cases, while females (268) cases were recorded, indicating a significant increase in the number of infections among females compared to males. As for the geographical distribution, Basra governorate recorded the highest infection rate with 212 cases, followed by Anbar governorate with 187 cases, and Babil governorate with 27 cases, as shown in Fig. 8.

3.1.6. 20-44 years

The highest numbers of TB cases among males and females appear in this age group, with a noticeable increase in the number of cases among males. The total number of cases in this category amounted to 1406 cases, of which 717 were among males, and 689 were among females. As for the geographical distribution, Basra governorate recorded the highest infection rate with 580 cases, followed by Anbar governorate with 191 cases, and Baghdad governorate with 150 cases, as shown in Fig. 9.

3.1.7. 45-64 years

The number of tuberculosis cases continues to increase between males and females, with a slight decrease in the gender gap, as females recorded a higher number of cases than males in this age group. The total number of infections amounted to 786 cases, of which 379 were males and 407 were females. As for geographical distribution, Basra governorate recorded the highest infection rate with 373 cases, followed by Baghdad governorate with 83 cases, and Babil governorate with 61 cases, as shown in Fig. 10.

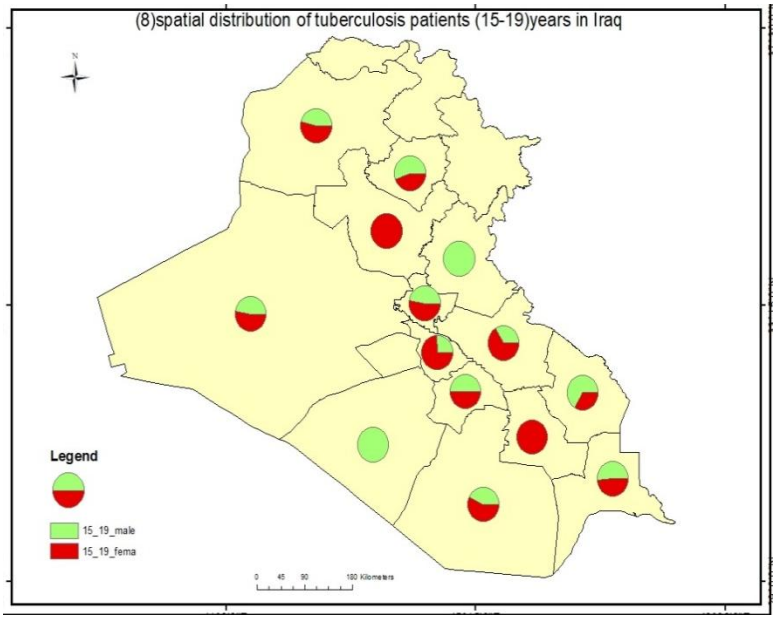

Fig. 8 Spatial distribution of (15-19 years) category using the ARG GIS10.8 program and relying on Table 2.

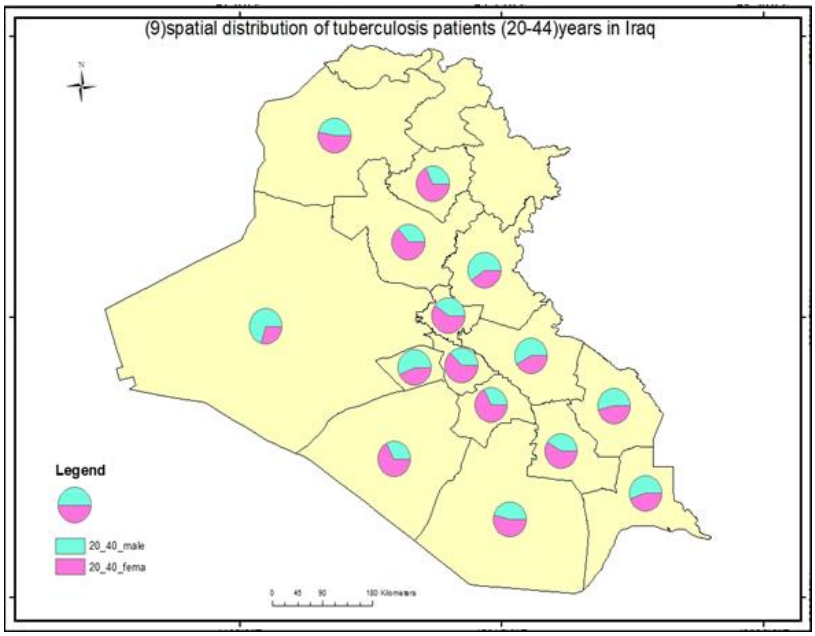

Fig. 9 Spatial distribution of (20-44 years) category using the ARG GIS 10.8 program and relying on Table 2.

3.1.8. 65 years and above

There is a convergence in the number of tuberculosis cases between males and females in this age group, as the numbers are almost equal between the two sexes. The total number of infections amounted to 325 cases, including 181 cases among males and 144 cases among females, indicating an increase in the number of infections among males compared to females. As for the geographical distribution, Basra governorate recorded the highest infection rate with 111 cases, followed by Wasit governorate with 87 cases, and Nineveh governorate with 27 cases, as shown in Fig. 10.

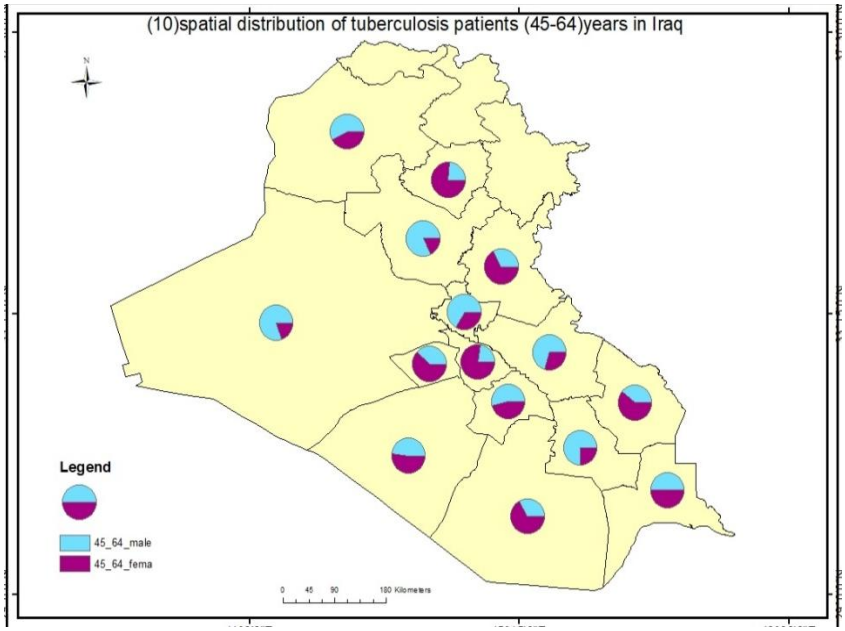

Fig. 10 Spatial distribution of (45-65 years) category using ARG GIS 10.8 program and relying on Table 2.

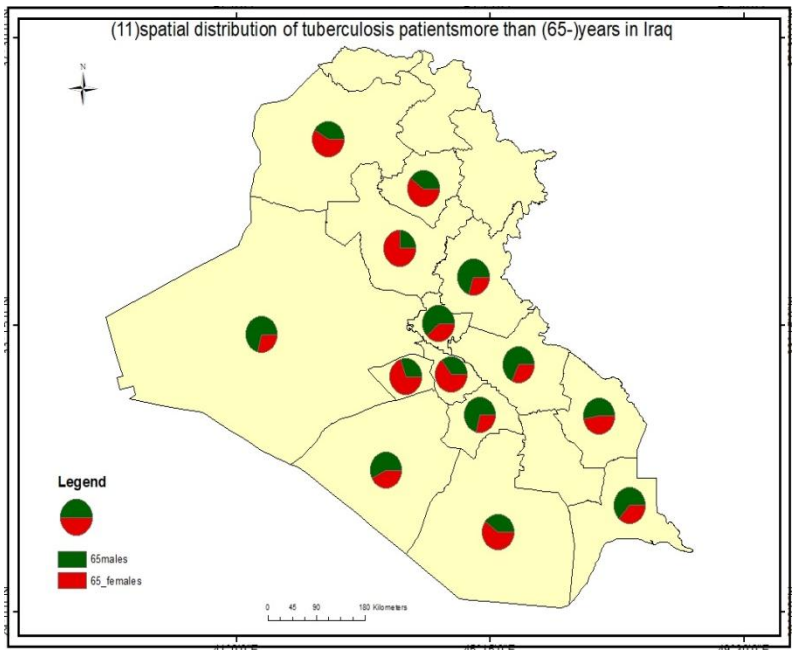

Fig. 11 Spatial distribution of (over 65 years) category using the ARG GIS 10.8 program and relying on Table 2.

There is a gradual increase in the number of disease cases with increasing age among both males and females for the categories, and a gender gap appears in some age groups, where the number is higher among males compared to females, and the numbers converge between males and females in the age group 65 and above.

3.2.Statistical Analysis and Distribution

The statistical analysis of the two tables highlights several important points in studying the distribution of TB infections in Iraq over the years 2014 - 2022 by governorates and age groups.

3.2.1. Total infections in 2022;

The total number of cases in 2022 amounted to 7678, with males 4529 and females 3149. The data show that there is a slight edge in the number of injuries among males compared to females.

3.2.2. Distribution in age groups (2022)

The 20-44 age group was the most affected by both genders, accounting for 16.76 % of male injuries and 16.11 % of female injuries. This was followed by the 54-64 age group, which accounted for 22.42 % of injuries among males and 11.22 % among females. The “less than a year” age group was the least affected, accounting for 0.42 % of injuries among males and 0.28 % among females. Older age groups, such as 65 years and above, recorded lower percentages of injuries, with 4.18 % among males and 3.37 % among females.

3.2.3. Differences between males and females

The gap between males and females varies significantly across several age groups, with males predominating in older age groups, especially in the 45-64 age group. Although males predominate in some groups, females show a higher proportion of injuries in some age groups, especially in the 5-9 age group.

3.2.4. Geographical distribution

Basra governorate recorded the highest number of cases in 2022 (1790 cases among males and 1482 cases among females), followed by Baghdad governorate (1874 cases). Muthanna governorate was among the governorates that recorded the lowest number of infections.

4. Summary and Conclusions

This research aims to inspect the incidence of tuberculosis in Iraq in terms of temporal and spatial variation using descriptive and analytical methods. The former was employed to obtain statistics, while the latter applied GIS and Arc GIS 10.8 to assess spatial variation and create a geographical database. Various conclusions can be drawn:

1. A temporal variation in the increase of TB cases was noticed across the governorates of Iraq from 2014 to 2022.
2. The highest number of infected people was observed in the governorates of Basra, Baghdad, and Wasit.
3. For most cases, the percentage of male patients was higher than that of female patients.
4. The number of infections is directly proportional to the age (for both males and females). TB incidence increased progressively with advancing age among both males and females.

5. In the age group (20-44 years) the no. of male patients is higher than females since most of them are the productive and breadwinning people in Iraqi society.
6. In the age groups (1-19 and 45- 64 years), the number of female patients is the highest.

This study demonstrated the potentially dangerous spread of tuberculosis infection in Iraq. Thus, it is essential to increase health awareness and education regarding the prevention and treatment of this disease among the infected, especially in locked places (such as prisons). Furthermore, health teams should emphasize vaccination, follow up on infected cases, pay attention to vulnerable groups and students, especially in the childhood stage, and sensitize them through health campaigns. Periodic examinations for the most infected group should also be conducted, and finally, young people should be taught about the dangers of smoking, especially in cafes, to avoid infection.

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