Research article

# Spatial distribution of vaccine-preventable diseases in central Iran in 2015–2018: A GIS-based study

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## ARTICLE INFO

## ABSTRACT

Vaccination is the second most effective health measure to maintain public health and prevent diseases after providing safe drinking water. This study aimed to determine the geographical distribution of vaccine-preventable diseases (VPDs) in Qom Province in four years (2015–2018) using Geographic Information System (GIS). In this cross-sectional study, the indicators of VPDs surveillance were extracted from the VPDs surveillance system at the Centers for Disease Control and Prevention (CDC) in Qom University of Medical Sciences. They were further evaluated, and the incidences of VPDs in the study years were investigated. Finally, the spatial distribution map of VPDs was provided for surveillance quality in each Qom district by Arc GIS 10.3 software. The annual incidence rate (AIR) was estimated to be 18.47 for hepatitis B, 0.29 for measles, 0.13 for rubella, 0.09 for pertussis, 0.29 for diphtheria and 0.91 for acute flaccid paralysis (AFP). The highest incidences of AFP, rubella and measles were observed in Markazi district. Salafchegan was a district with the highest incidence of diphtheria, and the highest incidence rate of hepatitis B was observed in Khalajestan district. In addition, all pertussis cases were reported from Qom city. According to thematic maps of GIS, the annual incidence rate of VPDs in Qom Province was lower than the mean rate in Iran. Nevertheless, it is highly recommended that a high immunization coverage should be done in the childhood and good surveillance indicators such as non-disease discarded rate, and the proportion of suspected cases with an adequate investigation should be used to monitor VPDs.

## 1. Introduction

According to the World Health Organization (WHO) reports, vaccination is the most effective health measure to maintain public health and prevent diseases after providing safe drinking water. Vaccines and immunization have played an important role in community health in the last century [1]. Vaccine-preventable diseases (VPDs) are defined as some communicable diseases, especially a range of bacterial and viral diseases that can be prevented effectively by a vaccine [2]. The WHO has recommended several effective vaccines for global use in order to prevent communicable diseases since the initiation of the Expanded Program on Immunization (EPI) [3]. Vaccination is the most effective healthcare intervention to improve children's health. Throughout the period from 2000 to 2017, measles vaccination has been able to prevent about 21.1

million children from measles all over the world [4]. According to the WHO report, a large number of children in the world continue to die from vaccine-preventable diseases annually: 89,000 people by pertussis in 2008, 110,000 people by measles in 2017, 34,000 people by neonatal tetanus in 2015, 4,000 people by bacterial meningitis in 2009 and 887, 000 people by hepatitis B in 2015 [4, 5, 6, 7]. The incidence of vaccine-preventable diseases in different areas of the world and Iran have been investigated previously [8]. For instance, the prevalence of HBV infection among high-risk groups in Iran is reported to be 4.8% (95% confidence interval: 3.6%–6.1%) [9]. Furthermore, the incidence rate of confirmed measles cases (clinically + epidemiologic + laboratory) in Iran is found to be 0.85 to 2 per million. Moreover, the incidence of rubella has been less than one per million populations since 2010 [10]. Diphtheria is fatal in 5–10% of cases with a higher mortality rate in young

children [11]. In Iran, VPDs include hepatitis B, diphtheria, tetanus, pertussis (whooping cough), measles, rubella, mumps, AFP, tuberculosis and bacterial meningitis [12]. In recent years, there have been many successes against VPDs in Iran [13]. Eliminating measles, congenital rubella syndrome, neonatal tetanus and sustained polio-free status on the one hand and controlling diphtheria, pertussis, hepatitis B and mumps on the other have been among the most important achievements of the EPI in Iran over the past few years [14, 15, 16, 17, 18, 19]. An accurate and reliable database is considered necessary to monitor and control communicable diseases, including VCDs and the improvement of the EPI [12]. It seems that the Geographic Information System (GIS) can be considered as an important tool to make use of the VPD database. This geographical system is used to collect, save, manipulate, update, analyze, present and display geographic information [20].

In recent years, spatial techniques and GIS have been increasingly utilized in the field of public health [21]. Several studies have been conducted by GIS in the field of public health and medical sciences in Iran. For instance, Jesri et al. determined the spatial analysis of bacterial meningitis [22], and Nejati et al. sought to investigate scorpions and scorpionism in the central desert of Iran [23]. Moreover, Salimi et al. investigated the spatio-temporal distribution analysis of zoonotic cutaneous leishmaniasis in Qom Province [24]. Therefore, this study aimed to determine the spatial distribution of VPDs in Qom Province by GIS from 2015 to 2018.

## 2. Materials and methods

### 2.1. Study area

In this cross-sectional study, the indicators of VPDs surveillance were evaluated in all districts of Qom Province over a period of four years (2015–2018). Qom Province is located in central Iran covering an area of 11,526 km$^2$ including desert, semi-desert and mountainous areas. Based on the 2016 national census, the population of this province is 1, 292, 283 in 383, 532 families. This province has five districts: Jafarabad (desert), Khalajastan (mountainous), Markazi (desert), Kahak (mountainous) and Salafchegan (semi-desert) [22] (Figure 1).

### 2.2. Data collection

Three different data sources were used in this study including different areas of Qom Province in the GIS shape file, the population census of 2016 for each district and the incidence of VPDs in the study period. The surveillance data of VPDs were extracted from the VPDs surveillance system at the Centers for Disease Control and Prevention (CDC) in Qom University of Medical Sciences owned and managed by Iran's Ministry of Health and Medical Education (MOHME).

The epidemiological data of patients were collected in standard forms and consisted of different variables such as suspected (having an epidemiological link with a confirmed case) and confirmed (cases with laboratory test positive) cases, age, gender, nationality (Iranian/non-Iranian), residence and district.

### 2.3. Data analysis

After data collection in Microsoft Office Excel 2010, the spatial distribution of VPDs was provided in GIS-based maps for surveillance quality in each Qom district using Arc GIS 10.3 software (http://www.esri.com/arcgis). First, the incidence of VPDs in the study period was calculated. Then, the 4-year incidence rate (IR) was mapped on district digital maps based on a scale of 1/50000. All analyses were carried out by district-level precision as basic units of analysis. The cutoff point for showing the spatial distribution was the incidence rate of diseases.

## 3. Results

The total population of Qom Province in four years was 1,292,283 based on the 2016 census (the mean number in the study period). The distribution of people among different age groups were 129,605 (0–4 years old), 205,627 (5–15 years old), 335,243 (15–30) and 621,808 (over 30 years old). The 4-year incidence rate (IR) was the primary outcome of this study and was estimated based on the cumulative number of patients for each VPD.
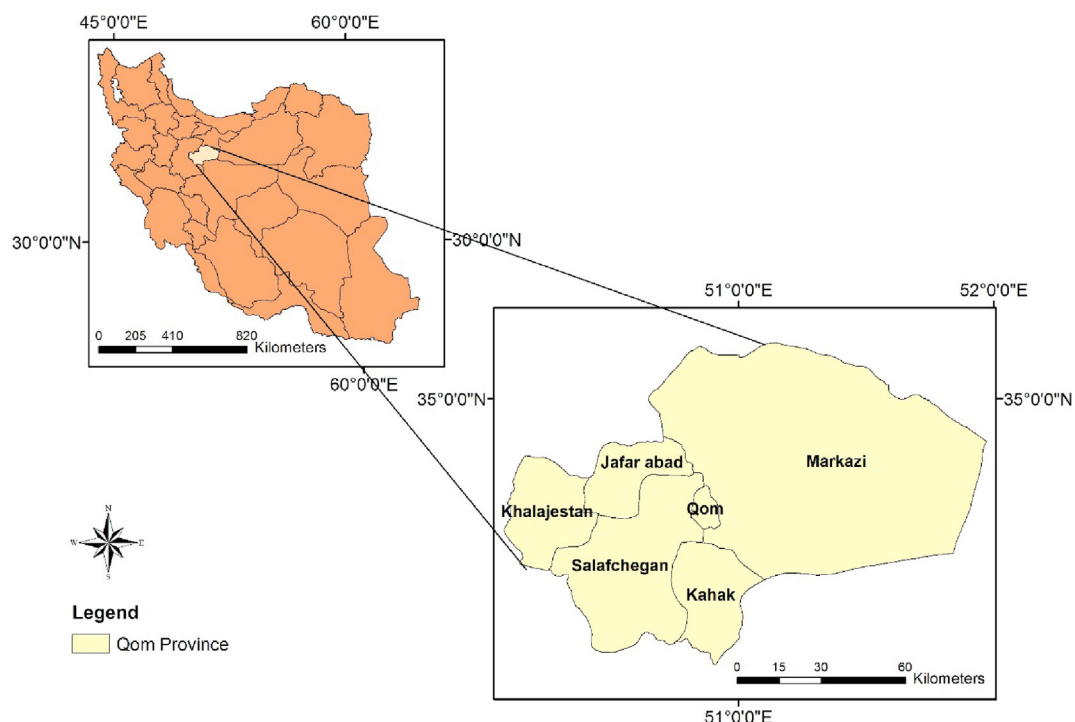


**Figure 1.** The geographical situation of the study area; Qom Province, central Iran.

### 3.1. Hepatitis B

The 4-year IR of hepatitis B was estimated to be 73.90. Also, the annual incidence rate (AIR) was 18.47. The incidence rate of hepatitis B showed a positive relationship with age, and the highest rate was observed in the over-30 age group (120.61). The sex ratio of hepatitis B was 1.5 (573/382). More than 92.5% of hepatitis B cases were located in the urban areas (884/955), and 92.77% (886/955) of cases were Iranian (Table 1).

### 3.2. Measles

The findings depicted in Table 2 show that the 4-year IR of measles was 1.16. Additionally, the annual incidence rate (AIR) was 0.29. The incidence rate of measles had a positive relationship with age, and the lowest rate was observed in the 0–4 age group (6.94). The sex ratio of the measles disease was 0.67 (6/9). More than 73.3% of measles patients were resident in the urban areas (11/15) and 73.3% (11/15) of cases were Iranian as well (Table 2).

### 3.3. Rubella

The IR of rubella was 0.54 in the 4-year period of study. Moreover, the annual incidence rate equaled 0.13. The incidence rate of rubella in Qom Province indicated a positive relationship with age, and the highest rate was observed in the 0–4 age group (1.54). The sex ratio of rubella was estimated to be 2.5 (5/2). Most cases (85.71%, 6/7) were located in urban areas, and more than half of patients (71.42%) were Iranian (Table 3).

### 3.4. Pertussis

The 4-year IR of pertussis was 0.38. The annual incidence rate was estimated to be 0.09. The incidence rate of pertussis had a positive relationship with age, and the highest rate was observed in the 0–4 age group (100%). The sex ratio of pertussis was 0.25 (1/4). All pertussis cases (100%) lived in urban areas, and 60% (3/5) of patients were Iranian (Table 4).

### 3.5. Diphtheria

As observed in Table 5, the 4-year IR of diphtheria was 1.16 (the annual incidence rate (AIR) was estimated to be 0.29). The incidence rate of diphtheria had a positive relationship with age, and the highest rate was observed in the 15–29 age group (1.79). The sex ratio of diphtheria was estimated to be 2.75 (11/4). The confirmed cases were more common in males (73.33%), urban residents (93.33%) and Iranians (93.33%) (Table 5).

### 3.6. Suspected AFP

Based on the results shown in Table 6, the 4-year IR of suspected AFP was 3.64 (the annual incidence rate was 0.91). The incidence rate of suspected AFP in 2015–2018 in Qom Province revealed a positive relationship with age, and the highest rate was observed in the 5–14 age group (14.10). The sex ratio of suspected AFP was 0.8 (21/26). The majority of suspected AFP cases (91.49%) were residents in urban areas (43/47) and Iranian (85.71%).

The spatial distributions of VPDs in Qom Province are presented in Table 7. Based on the results (Table 7 and Figure 2), the IR of pertussis was 0.41 in the city of Qom.

Figure 2 depicts the spatial distribution of new cases of VPDs in Qom Province in the study period. Based on these maps, the highest incidences of AFP, rubella and measles were observed in Markazi district. Salafchegan was a district with the highest incidence of diphtheria and Khalajestan district had the highest incidence rate of hepatitis B. Besides, all pertussis cases were reported from the city of Qom.

## 4. Discussion

This study investigated the 4-year spatial distribution of some vaccine-preventable diseases (VPDs) including AFP, diphtheria, pertussis, rubella, measles and hepatitis B using the GIS based maps. The 4-year and annual IR of hepatitis B were estimated to be 73.90 and 18.47 per 100,000 people, respectively, and there was an increase in the aged population so that the AIR was 30 per 100,000 people in people who were 30 years old and over. Moreover, the spatial distribution of hepatitis B showed that the highest incidence rate of the disease was in Khalajestan district. The 4-year and annual IR of measles were 1.16 and 0.29 per 100,000 people, respectively. In addition, based on GIS spatial analysis, most cases suffering from measles were reported from Markazi district in the desert areas. The increased rate of incidence showed an increase after the immunization of measles in childhood. Based on the findings of recent studies, the immunization coverage of measles in Iran is 99.2% for MMR1 and 97.9% for MMR2 [25]. According to the results of other studies, the surveillance indicators for measles (as the ability to detect and confirm cases rapidly and accurately) in Qom Province were good and higher than the mean of Iran indicators [26, 27].

The annual and 4-year IR of pertussis were 0.09 and 0.38 per 100,000 populations. The results of this study revealed that the highest rate was observed in the 0–4 age group, and there was not a difference between boys and girls regarding the incidence rate (1/4). Ghorbani et al. reported that in three years (2011–2013), a total of 3,629 suspected pertussis cases were detected in Iran, and 239 (6.6%) cases were laboratory-confirmed and others were considered as clinical diagnosis cases [28]. Based on the findings of the current study, the total number of suspected cases was 93, and the total number of confirmed cases was six in four years. Besides, the spatial distribution of this disease in different districts of Qom Province showed that the majority of cases were residents of the city of Qom.

Moreover, according to the results, the 4-year and annual IR of diphtheria were 1.16 and 0.29, and the highest rate of diphtheria was observed in the 15–29 age group. Boys were more affected by diphtheria (sex ratio = 2.75). However, the immunization surveys in Iran have shown that the vaccination coverage of the first dose of DPT1 is 99.2%, decreasing to 98% in the 18th-month reminder of DPT [25]. Yet, the delay in immunization of DPT has increased in reminders of the vaccine [29].

**Table 1.** The incidence rate of hepatitis B based on gender, residence place and age groups in Qom Province in 2015–2018.

| Age Group | population | Total number (%)of cases | | Male | Female | Urban | Rural | Iranian | Non- Iranian |
|---|---|---|---|---|---|---|---|---|---|
| | | N (%) | Incidence (per 100,000) | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) |
| 0–4 | 129605 | 3 (0.32) | 2.31 | 1 (0.17) | 2 (0.52) | 2 (0.23) | 1 (1.41) | 2 (0.23) | 1 (1.45) |
| 5–14 | 205627 | 4 (0.42) | 1.94 | 1 (0.17) | 3 (0.79) | 3 (0.34) | 1 (1.41) | 3 (0.34) | 1 (1.45) |
| 15–29 | 335243 | 198 (20.73) | 59.06 | 74 (12.92) | 124 (32.46) | 162 (18.32) | 36 (50.70) | 170 (19.19) | 28 (40.58) |
| Over 30 | 621808 | 750 (78.53) | 120.61 | 497 (86.74) | 253 (66.23) | 717 (81.11) | 33 (46.48) | 711 (80.24) | 39 (56.52) |
| Total | 1292283 | 955 (100) | 73.90 | 573 (100) | 382 (100) | 884 (100) | 71 (100) | 886 (100) | 69 (100) |

**Table 2.** The incidence rate of measles based on gender, residence place and age groups in Qom Province in 2015–2018.

| Age Group | population | Total number (%)of cases | | Male | Female | Urban | Rural | Iranian | Non- Iranian |
|---|---|---|---|---|---|---|---|---|---|
| | | N (%) | Incidence (per 100,000) | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) |
| 0–4 | 129605 | 9 (60.00) | 6.94 | 3 (50.00) | 6 (66.67) | 6 (54.54) | 3 (0.75) | 8 (72.72) | 1 (0.25) |
| 5–14 | 205627 | 3 (20.00) | 1.46 | 2 (33.34) | 1 (11.11) | 3 (27.27) | 0 (0.00) | 2 (18.18) | 1 (0.25) |
| 15–29 | 335243 | 3 (20.00) | 0.89 | 1 (16.66) | 2 (22.22) | 2 (18.19) | 1 (0.25) | 1 (10.00) | 2 (0.50) |
| Over 30 | 621808 | 0 (0.00) | 0.00 | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| Total | 1292283 | 15 (100) | 1.16 | 6 (100) | 9 (100) | 11 (100) | 4 (100) | 11 (100) | 4 (100) |

**Table 3.** The incidence rate of rubella based on gender, residence place and age groups in Qom Province in 2015–2018.

| Age Group | population | Total number (%)of cases | | Male | Female | Urban | Rural | Iranian | Non- Iranian |
|---|---|---|---|---|---|---|---|---|---|
| | | N (%) | Incidence (per 100,000) | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) |
| 0–4 | 129605 | 2 (28.57) | 1.54 | 2 (40.00) | 0 (0.00) | 2 (33.34) | 0 (0.00) | 2 (40.00) | 0 (0.00) |
| 5–14 | 205627 | 2 (28.57) | 0.97 | 1 (20.00) | 1 (50.00) | 2 (33.33) | 0 (0.00) | 2 (40.00) | 0 (0.00) |
| 15–29 | 335243 | 3 (42.86) | 0.89 | 2 (40.00) | 1 (50.00) | 2 (33.33) | 1 (100) | 1 (20.00) | 2 (100) |
| Over 30 | 621808 | 0 (0.00) | 0.00 | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| Total | 1292283 | 7 (100) | 0.54 | 5 (100) | 2 (100) | 6 (100) | 1 (100) | 5 (100) | 2 (100) |

**Table 4.** The incidence rate of pertussis based on gender, residence place and age groups in Qom Province in2015–2018.

| Age Group | population | Total number (%)of cases | | Male | Female | Urban | Rural | Iranian | Non- Iranian |
|---|---|---|---|---|---|---|---|---|---|
| | | N (%) | Incidence (per 100,000) | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) |
| 0–4 | 129605 | 5 (100) | 3.86 | 1 (20) | 4 (80) | 5 (100) | 0 (0.00) | 3 (60) | 2 (40) |
| 5–14 | 205627 | 0 (0.00) | 0.00 | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| 15–29 | 335243 | 0 (0.00) | 0.00 | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| Over 30 | 621808 | 0 (0.00) | 0.00 | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| Total | 1292283 | 5 (100) | 0.38 | 1 (00) | 4 (100) | 5 (100) | 0 (0.00) | 3 (100) | 2 (100) |

**Table 5.** The incidence rate of diphtheria based on gender, residence place and age groups in Qom Province in 2015–2018.

| Age Group | population | Total number (%)of cases | | Male | Female | Urban | Rural | Iranian | Non- Iranian |
|---|---|---|---|---|---|---|---|---|---|
| | | N (%) | Incidence (per 100,000) | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) |
| 0–4 | 129605 | 1 (6.67) | 0.77 | 1 (9.09) | 0 (0.00) | 1 (7.14) | 0 (0.00) | 1 (7.14) | 0 (0.00) |
| 5–14 | 205627 | 3 (20.00) | 1.46 | 3 (27.27) | 0 (0.00) | 3 (21.43) | 0 (0.00) | 3 (21.42) | 0 (0.00) |
| 15–29 | 335243 | 6 (40.00) | 1.79 | 6 (54.55) | 0 (0.00) | 6 (42.86) | 0 (0.00) | 5 (35.72) | 1 (100) |
| Over 30 | 621808 | 5 (33.33) | 0.80 | 1 (9.09) | 4 (100) | 4 (28.57) | 1 (100) | 5 (35.72) | 0 (0.00) |
| Total | 1292283 | 15 (100) | 1.16 | 11 (100) | 4 (100) | 14 (100) | 1 (100) | 14 (100) | 1 (100) |

**Table 6.** The incidence rate of suspected AFP based on gender, residence place and age groups in Qom Province in 2015–2018.

| Age Group | population | Total number (%)of cases | | Male | Female | Urban | Rural | Iranian | Non- Iranian |
|---|---|---|---|---|---|---|---|---|---|
| | | N (%) | Incidence (per 100,000) | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) |
| 0–4 | 129605 | 18 (38.30) | 13.88 | 10 (47.62) | 8 (30.77) | 15 (34.88) | 3 (75.00) | 17 (40.48) | 1 (20.00) |
| 5–14 | 205627 | 29 (61.70) | 14.10 | 11 (52.38) | 18 (69.23) | 28 (65.12) | 1 (25.00) | 25 (59.52) | 4 (80.00) |
| 15–29 | 335243 | 0 (0.00) | 0.00 | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| Over 30 | 621808 | 0 (0.00) | 0.00 | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| Total | 1292283 | 47 (100) | 3.64 | 21 (100) | 26 (100) | 43 (100) | 4 (100) | 42 (100) | 5 (100) |

During the 4-year period of the study, 43 new cases of suspected AFP were detected and were all removed. However, the annual incidence rate was 0.91, and the highest rate was observed in the 5–14 age group. The mean number of cases for Acute Flaccid Paralysis (AFP) in each year was 11, and the annual incidence rate was 0.91 in Qom Province. In terms of spatial distribution, the majority of suspected cases were reported from Markazi district due to some factors including differences in vaccine coverage and socio-economic conditions [30]. Nevertheless, in 2016, the total number of recorded AFP cases were 776 cases in Iran, and the non-polio AFP rate was estimated to be 4.2 per 100,000 populations in 15-year-old and younger age groups, which was lower than the mean incidence in Iran [31]. Spatial distribution of new cases of VPDs in Qom Province showed that the highest incidences of AFP, rubella and measles were observed in Markazi district because of limited knowledge

**Table 7.** The 4-year incidence rate of vaccine-preventable diseases based on different districts of Qom Province in 2015–2018.

| Area | Total Population | Pertussis | | Measles | | Rubella | | Hepatitis B | | Suspected AFP | | Diphtheria | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N (%) | Incidence /100,000 | N (%) | Incidence /100,000 | N (%) | Incidence /100,000 | N (%) | Incidence /100,000 | N (%) | Incidence /100,000 | N (%) | Incidence /100,000 |
| Qom city | 1212214 | 5 (100) | 0.41 | 11 (73.33) | 0.91 | 6 (85.71) | 0.49 | 884 (92.56) | 72.92 | 43 (91.48) | 3.54 | 14 (93.33) | 1.15 |
| Markazi district | 23273 | 0 (0.00) | 0.00 | 3 (20.00) | 12.89 | 1 (14.29) | 4.29 | 24 (2.51) | 103.12 | 2 (4.26) | 8.59 | 0 (0.00) | 0.00 |
| Kahak district | 20588 | 0 (0.00) | 0.00 | 1 (6.67) | 4.85 | 0 (0.00) | 0.00 | 10 (1.05) | 48.57 | 1 (2.13) | 6.82 | 0 (0.00) | 0.00 |
| Salafchegan district | 9938 | 0 (0.00) | 0.00 | 0 (0.00) | 0.00 | 0 (0.00) | 0.00 | 5 (0.52) | 50.31 | 0 (0.00) | 0.00 | 1 (6.67) | 10.06 |
| Khalajestan district | 7207 | 0 (0.00) | 0.00 | 0 (0.00) | 0.00 | 0 (0.00) | 0.00 | 12 (1.26) | 166.50 | 0 (0.00) | 0.00 | 0 (0.00) | 0.00 |
| Jafar Abad district | 19063 | 0 (0.00) | 0.00 | 0 (0.00) | 0.00 | 0 (0.00) | 0.00 | 20 (2.10) | 104.91 | 1 (2.13) | 5.24 | 0 (0.00) | 0.00 |
| Total | **1292283** | 5 (100) | 0.38 | 15 (100) | 1.16 | 7 (100) | 0.54 | 955 (100) | 73.90 | 47 (100) | 3.63 | 15 (100) | 1.16 |
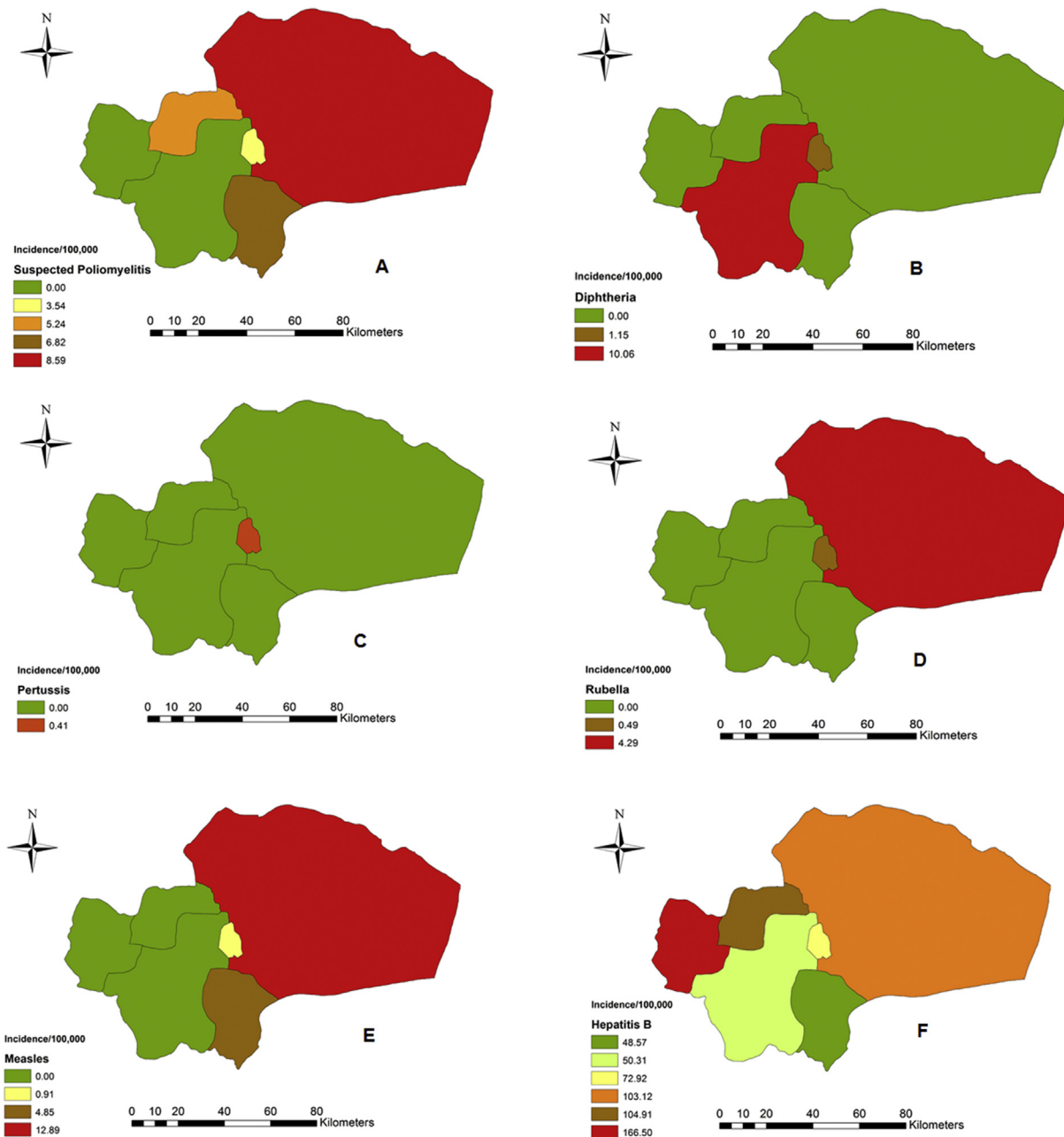


**Figure 2.** The spatial distribution of vaccine-preventable diseases in Qom Province, central Iran, in 2015–2018. A: Spatial distribution of suspected AFP B: Spatial distribution of Diphtheria. C: Spatial distribution of Pertussis. D: Spatial distribution of Rubella. E: Spatial distribution of Measles. F: Spatial distribution of Hepatitis B.

among people, low vaccination coverage and poor access to health care services. The city of Qom is located in Markazi district with more than 95.6% of all Qom Province population.

## 5. Conclusions

According to the thematic GIS maps, the annual incidence rate of VPDs in Qom Province was lower than the national mean incidence in Iran. Nevertheless, high immunization coverage in childhood and good surveillance indicators in monitoring VPDs in Qom province are required. The required surveillance indicators include non-disease discarded rate, the proportion of suspected cases with an adequate investigation, the proportion of cases with adequate specimen collection and the proportion of cases for whom laboratory results are acceptable. Therefore, maintaining high vaccination coverage and improving the surveillance indexes should be considered as essential measures.

## Declarations

### Author contribution statement

A. Saghafipour: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

A. Mohammadbeigi: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

N. Jesri: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

M. Jooshin: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

F. Tarkhan: Performed the experiments.

### Funding statement

This work was supported by the Research and Technology Center of Qom University of Medical Sciences (IR.MUQ.REC.1398.130).

### Competing interest statement

The authors declare no conflict of interest.

### Additional information

No additional information is available for this paper.

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