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Monitoring Vaccination Coverage in Istanbul Using the Lot Quality Assurance Sampling and Geographic Information System

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The quality of vaccination services provided for children aged 12 – 23 months was determined in different districts of Istanbul, Turkey. Quality was assessed through a lot quality assurance sampling method, using data extracted from interviews conducted in 2001 with the mothers or carers of the children. Concurrently, geographic information system technology was used for integrated evaluation of the data from different lots and for presentation of the results as thematic maps. The results of this study helped to identify districts of the city in which vaccination services were below the expected level of quality and where an unacceptable number of children were not being fully vaccinated. Subsequent to this study, actions were taken by the agencies responsible to improve the coverage and quality of the vaccination services in these districts of Istanbul.

KEY WORDS: Lot quality assurance sampling (LQAS), Expanded Programme on Immunization (EPI); Vaccination services quality; Epidemiology; Geographic information systems (GIS); Thematic maps

Introduction

Istanbul is the most crowded city of Turkey having a population of over 12 million people. The city is divided into 32 districts, each of which includes settlement areas classified as rural, urban or slum. Each district has different socio-demographic, economic and cultural characteristics. There is a significant disparity in the healthcare services provided in these districts.

According to the Expanded Programme on Immunization (EPI), a 1-year old child should be fully immunized against tuberculosis, diphtheria, pertussis, tetanus, poliomyelitis, hepatitis B and measles.[1] The proportion of the population that has been vaccinated has been used to evaluate the coverage provided by individual immunization services, where coverage is defined as the extent of the population at risk that has been vaccinated. In cases where the data used to calculate the proportion of people vaccinated are unreliable, more accurate information has been acquired by careful research.[2,3]

Lot quality assurance sampling (LQAS), otherwise known as the Lot Quality (LQ) technique, is a quality control tool adopted from industry and is based on collecting important management information by using small-size samples randomly taken from specific service and settlement units. For example, in industry similar items, such as products, might be grouped to form a homogeneous lot and a simple random sample would then be taken from that lot to test for quality. Items would then be accepted or rejected on the basis of pre-defined decision values.

LQAS is a quick and easy method that can be used by healthcare managers at all levels to monitor and evaluate health programmes.[3–5] In healthcare, the sample is usually taken from a group of people that constitute the 'lot'. Briefly, LQAS is designed to evaluate whether healthcare services comply with the expectations of the healthcare manager in terms of service coverage and quality; rather than to measure these parameters directly. Within this framework, LQAS provides quick answers to clear questions. For example, the manager may wish to identify which healthcare services are good or poor and also the locations where service quality falls below an acceptable level.[3–6]

Recently, LQAS-based applications have been used in monitoring and evaluating health programmes, such as oral rehydration therapy, immunization programmes and family planning, health education, and registration systems. Such applications have especially increased the monitoring of EPI which has been introduced under the leadership of the World Health Organization (WHO).[7–12]

The most important advantages of the LQAS method are that: (a) it can be applied to small populations; (b) it can be used to make evaluations on individual lots (lots can be health services units, province, district and subdivision, etc.); (c) it allows for comparison to be made between different lots within the population area studied; (d) it enables comments to be made very rapidly after the collection of data; and (e) it allows managers to work with small sampling groups at a level of accuracy between ±1 and ±10, and at a level of confidence between 90 and 99%. In spite of these advantages, however, there are some disadvantages with the LQAS method. For example, when evaluating vaccination coverage for an area (the proportion of people who have received a vaccination), individual lots can only be assigned as acceptable or unacceptable/rejected. It is not possible to determine the proportion of vaccinated children within each lot with this technique; it is only possible to obtain an opinion on each of the lots. Vaccination coverage (the proportion of people vaccinated) at a regional scale can only be calculated by combining the data from every lot.[3,13,14] In this study, as in several studies presented in the literature,[15–18] geographic information system (GIS) technology was used to overcome the constraints of the LQAS technique.

Utilization of spatial data has increased among specialists in different disciplines as it enables them to improve the planning of their work and aids more effective presentation of the results. Within this context, spatial data have become especially useful for improving our understanding of environmental factors. GIS, which involves data organization, analysis, use and presentation, is a technology often used in different disciplines to find solutions to global problems through a systematic approach. It is a multi-disciplinary tool and can be used for different applications, such as city planning, transport, agriculture, disaster management, navigation and medicine, and has become an indispensable tool for small- or large-scale epidemiological studies. Production of epidemiological maps for monitoring the daily operation and management of public health programmes has become an important application of GIS technology.[15–19]

Patients and methods

PATIENTS AND DATA COLLECTION

The LQAS technique has two types of use in the evaluation of vaccination services: (a) Lot Quality Assessment; and (b) Lot Quality Coverage Survey.[3] This study was conducted using both of these methods and was structured by considering the following eight stages.

1. Identification of target population and setting of assessment criteria

Coverage and performance of EPI in Istanbul were evaluated for vaccination against tuberculosis (Bacille Calmette Guérin; BCG), diphtheria, pertussis, tetanus (DPT), polio (oral polio vaccine; OPV), hepatitis B virus (HBV) infection and measles in children aged 12 – 23 months. Children were classified as 'fully vaccinated', 'not fully vaccinated' and 'unvaccinated' depending on the extent of their vaccination coverage.

2. Level of accuracy and confidence for the survey

The level of accuracy was set as ±3% and the level of confidence as 95%.

3. Estimation of total sample size

The sample size in order to achieve the required levels of accuracy and confidence was determined as 1066 children by considering declarations of the WHO[3], as represented in Table 1.

4. Estimation of the total population from which the target population is to be selected

The population of children was 166 257 in Istanbul in 2001. Samples were selected from this population according to the LQAS technique.

TABLE 1:
Sample size to achieve the required levels of accuracy and confidence was determined using declarations of the WHO[3]

Desired level of accuracy (%)	Desired level of confidence		
	90%	95%	99%
1	6718	9512	16 317
2	1688	2395	4130
3	751	1066	1840
4	423	600	1036
5	270	384	663
6	188	267	461
7	138	196	338
8	106	150	259
9	83	119	205
10	68	96	166

5. Determination of the number of lots to be studied

Although there are 32 official districts in Istanbul, a higher number of lots was used for the study since socio-demographic, economical and cultural characteristics may vary within the same district. A total of 19 districts were individually accepted as single lots (total of 19 lots) and another 13 districts were divided into either two or three lots (12 of the districts were accepted as divided into two individual lots [total of 24 lots] and one of the districts was accepted as divided into three individual lots [total of 3 lots]); hence an overall total of 46 lots were studied.

6. Determination of the minimum sample size for each lot and total sample size for the study area

The minimum sample size per lot was estimated as 24 by dividing total sample size by number of lots (1066/46 = 23.2). Total sample size was calculated as 1104 (46 × 24 = 1104).

7. Setting of the low and high threshold levels and a decision value for evaluation

The threshold levels are used to assess the performance of a lot. Two different threshold levels are recommended in the LQAS technique to distinguish between good and bad lots, judged in this study as 'acceptable' or 'unacceptable'.[3] The low threshold level was based on estimates of coverage obtained from various sources, including routine reporting, number of vaccines provided or past coverage surveys, while the high threshold value was based on the coverage goal set at the national level.

The decision value in this study was the highest number of unvaccinated children in a lot, but where the lot was still classified as 'acceptable'. Decision values depend on the lot sample size and on low and high thresholds.[3]

In this study, the low and the high threshold levels were determined as 65% and 95%, respectively, and the decision value was determined as 3 based on the WHO declaration presented in Table 2.

TABLE 2:
The decision value was determined as 3 for low and high threshold levels of 65% and 95%, respectively, using WHO data (for a minimum lot sample size of 24)[3]

Low threshold (%)	High threshold							
	60%	65%	70%	75%	80%	85%	90%	95%
30	12	12	11	10	10	9	8	6
35	12	11	10	10	9	8	7	6
40	11	10	10	9	8	7	7	6
45	10	9	9	8	8	7	6	5
50		9	8	8	7	6	5	5
55			8	7	6	6	5	4
60				6	6	5	4	4
65					5	5	4	3

8. Data collection

This study was conducted in Istanbul in 2001 and a revised version of questionnaires, first developed for use in WHO immunization studies, was used to collect attribute data.[3,14] A doctor and a nurse worked together to collect the data from each sampling region. In order to test that the questionnaires were being completed as required, direct interviews were conducted with the mother or carers of the children aged 12 – 23 months. Vaccination data (date and place of vaccination), if available, were acquired from the children's vaccination cards and, if not available from this source, were recorded based on verbal declarations from the mother or carer.

STATISTICAL ANALYSIS

All the data obtained from the lots in this study were spatial data, which can be evaluated independently. However, in order to be able to monitor these data as a whole and to make relative evaluations, the data were monitored with spatial references and managed from a database. For this purpose, the data (attribute data) collected according to the LQAS technique were organized in a GIS environment by transferring them to a relational database. Attribute data were then related to the geometric data (maps) of the study area by using GIS software. Thematic maps of the study area were produced by considering the vaccination state for each lot and for different types of vaccine.

Results

The results of the study revealed that 75.6% of the children aged 12 – 23 months in the study area were fully vaccinated; 20.7% were not fully vaccinated and the remaining 3.7% were not vaccinated at all.

The numbers of lots that were above the decision value of 3 (unacceptable vaccine services) were determined for each type of vaccine and are shown in Table 3.

The quality and coverage of the EPI was evaluated in different districts of Istanbul using the LQAS technique, in which lots were accepted or rejected on the basis of whether an acceptable number of children aged 12 – 23 months were fully vaccinated. If more than 3/24 children in a lot were unvaccinated the lot was rejected and the vaccination service for that lot was considered to be below the expected level of service quality. According to this criterion, the following results, for Istanbul, were introduced for each type of vaccination in stated lots with their lot numbers.

EVALUATION OF BCG VACCINATION

There were more than 3/24 unvaccinated children in four of the 46 lots, as presented in Fig. 1, which means that the quality of the vaccination services conducted was below the acceptable level in these lots.

TABLE 3:
The numbers of lots that were above the decision value of 3 (unacceptable vaccine services) for each type of vaccine (n = 46)

	Unvaccinated*	BCG	DPT3	OPV3	HBV3	Measles
Number of lots	1	4	10	19	21	19

*Decision value >3 across all vaccines.
BCG, Bacille Calmette Guérin; DPT3, diphtheria, pertussis, tetanus; OPV3, oral polio vaccine; HBV3, hepatitis B virus.

These four lots have poor socio-economic conditions and healthcare services are insufficient.

EVALUATION OF DPT3 VACCINATION

There were 10 lots which included more than 3/24 children who were not fully vaccinated for DPT in Istanbul because these children had not completely received the full total of three doses of DPT3 vaccine, hence they were classified as unvaccinated. These 10 lots, in which vaccination services fell below the acceptable level, are shown in Fig. 2.

EVALUATION OF OPV3 VACCINATION

There were 19 lots with more than 3/24 children who were not fully vaccinated with three doses of OPV (Fig. 3). Although OPV3 and DPT3 vaccines have to be applied simultaneously, the study revealed that the quality of OPV3 vaccination services was worse than that of DTP3 vaccination. This was mainly because some of the children were classified as unvaccinated because they had been vaccinated with Inactive Polio Vaccine (IPV) instead of OPV and the EPI says that OPV should be given against poliomyelitis in Turkey.[20] In some of these lots, socio-economic conditions were poor and the number of healthcare institutions was insufficient. In the other lots, socio-economic conditions were better and vaccination services were conducted by private hospitals or clinics which use the IPV vaccine instead of OPV.

EVALUATION OF HBV3 VACCINATION

The HBV3 vaccine should be given in three doses against hepatitis B infection and there were 21 lots with more than 3/24 children who were not fully vaccinated in this way in Istanbul (Fig. 4). HBV was only included in the EPI in 1998 in Turkey, therefore, difficulties in ensuring routine application of this vaccine were still occurring in 2001 when this research was conducted and is the main reason why the HBV3 vaccination services were found to be the poorest in this study.

EVALUATION OF MEASLES VACCINATION

The measles vaccine is normally given as a single dose to children aged 9 months. However, some paediatricians give this vaccine to children aged 15 months as the measles – mumps – rubella vaccine, hence some children were identified in the study at ages over 9 months who had not yet been vaccinated against measles. The quality of measles vaccination services was found to be 'unacceptable' in 19 lots (Fig. 5).

EVALUATION OF ALL VACCINES

In this study, one of the 46 lots was considered to be a high risk area since it had more than 3/24 unvaccinated children across all vaccines. This lot was in the rural area of the Gaziosmanpasa district which, compared with the other lots, has the poorest socio-demographic and economic conditions and lowest quality of health care services (Fig. 6). In the measles outbreak in Istanbul in 2001, most cases occurred in this region; five children were reported to have died of measles and a considerable number of the measles cases were unvaccinated children under the age of 5 years. A vaccination campaign was organized in this region to vaccinate all children aged between 9 months and 7 years in order to stop the outbreak.[21]

The quality of vaccination services in the other lots was considered to be 'acceptable' as measured against the decision value.

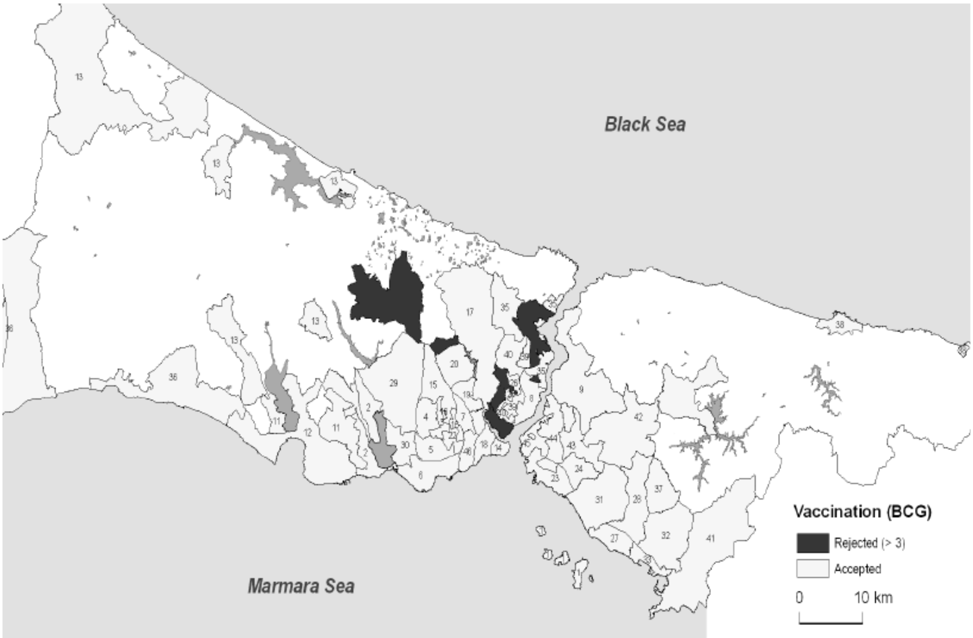

FIGURE 1: Evaluation of lots for BCG vaccination in Istanbul

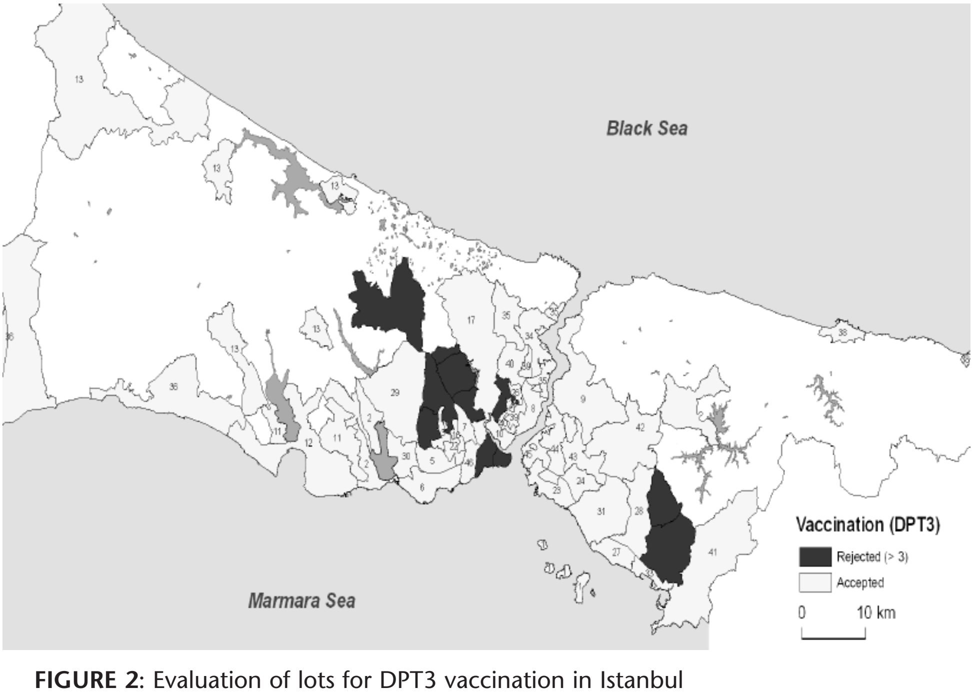

FIGURE 2: Evaluation of lots for DPT3 vaccination in Istanbul

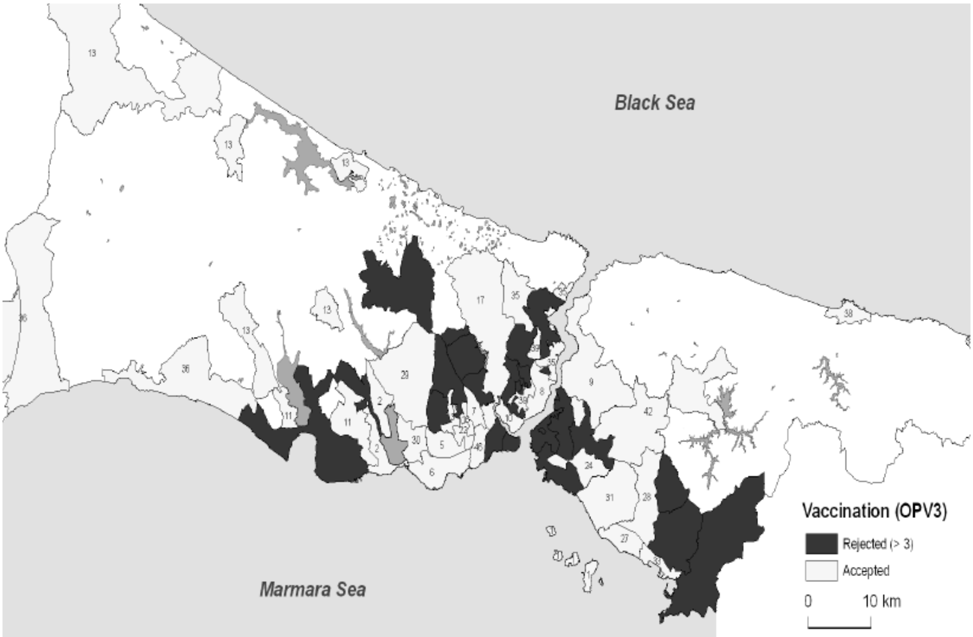

FIGURE 3: Evaluation of lots for OPV3 vaccination in Istanbul

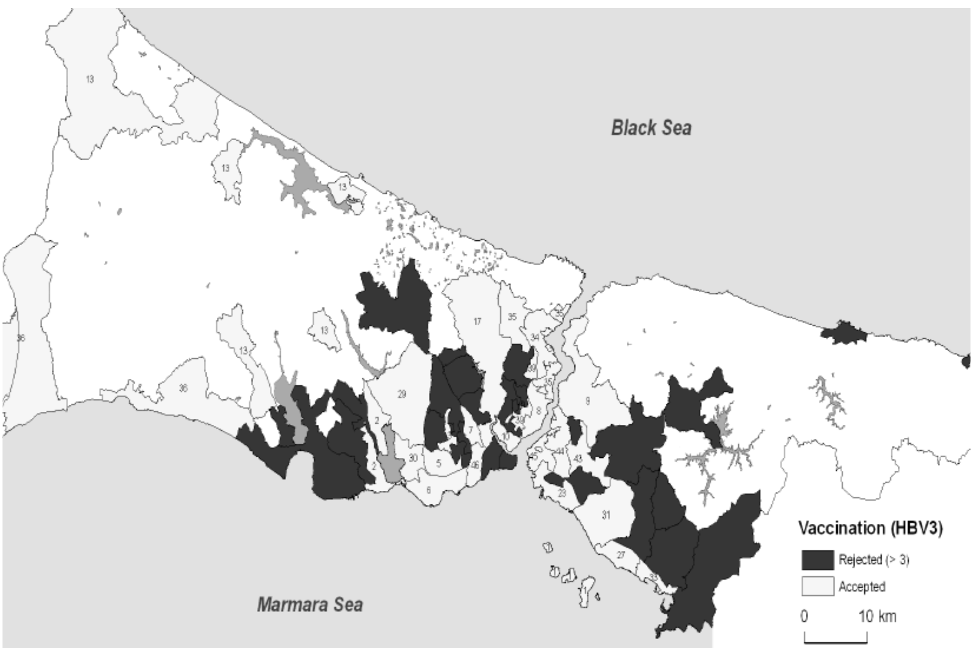

FIGURE 4: Evaluation of lots for HBV3 vaccination in Istanbul

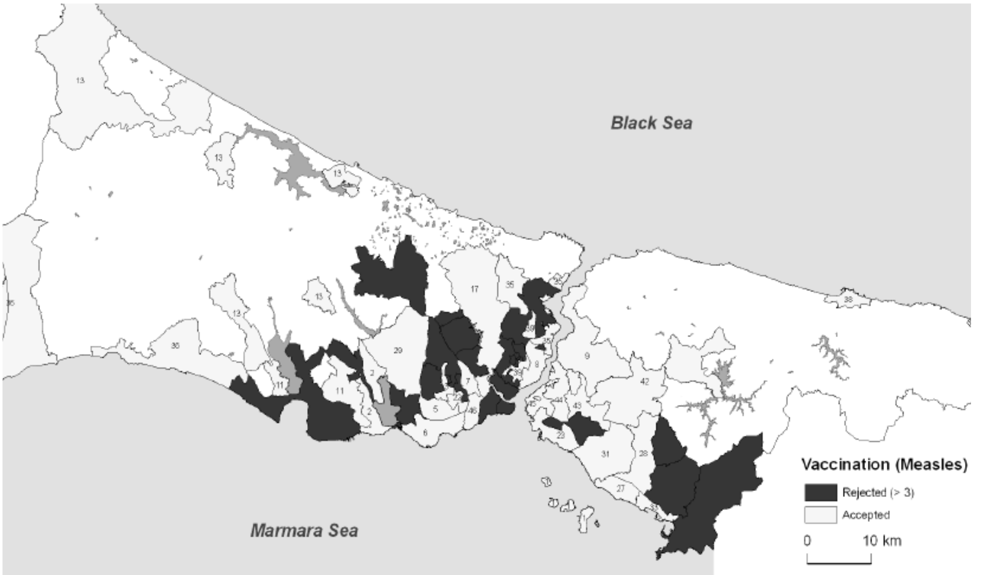

FIGURE 5: Evaluation of lots for the measles vaccination in Istanbul

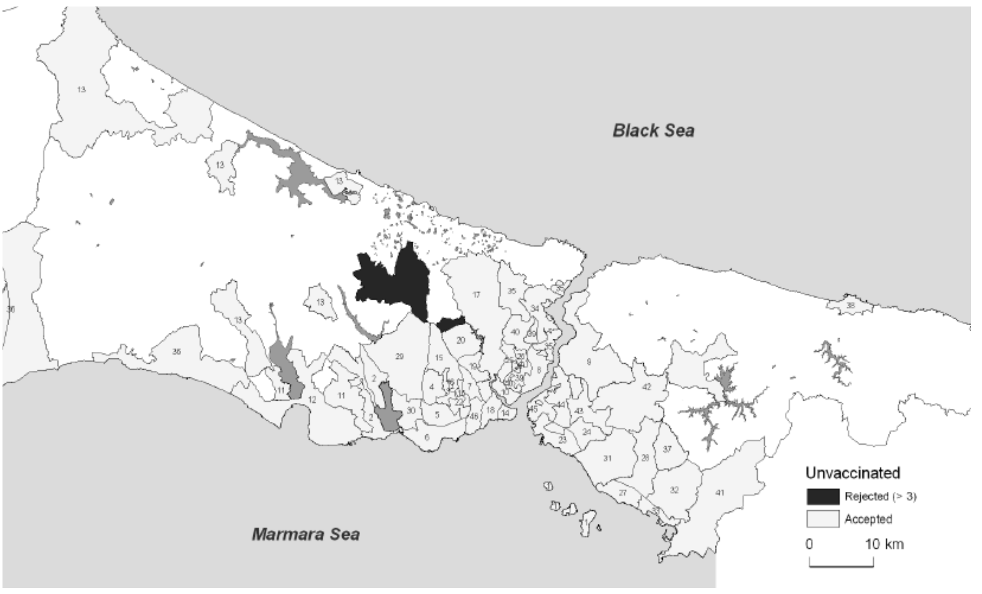

FIGURE 6: Evaluation of lots across all vaccines in Istanbul

Discussion

The quality of vaccination services was evaluated by the LQAS technique and GIS technology. GIS analysis allowed mapping of the quality of vaccination services in Istanbul and evaluation of the performance achieved by each of the lots that were studied. All of the results were visually traceable and problematic areas, in terms of the quality of vaccination services, were identified at the provincial level. Upon investigation of the research findings and the thematic maps it was possible to identify those vaccination services that failed to comply with the desired quality relative to the study criteria. These lots, in general, were in regions of Istanbul inhabited by families on low income and with poor and insufficient infrastructure and services. Quality of the vaccination services in Istanbul was, therefore, clearly affected by socio-demographic, economic and geographical conditions. As a result of this study, some improvements have been made to increase the coverage and quality of the services in the lots identified as unacceptable.

It is now possible to produce a vaccine preventable diseases risk map for Istanbul using thematic maps by taking the visual results of the GIS application and by considering the general conditions of the problematic districts in terms of vaccination services. As the number and extent of such studies are increased it will be increasingly possible to organize and conduct healthcare services in Istanbul more efficiently and effectively.

Examination of data through GIS in this study was done retrospectively. If, however, such a multidisciplinary study could be undertaken simultaneously with data acquisition, it would then be possible to take more immediate action in the lots that fall below an acceptable standard based on relative evaluation of the analyses, inquiries and common characteristics of the studied lots. Improvements in such multidisciplinary studies will provide health managers with the necessary scientific data to enable them to make more accurate decisions.

Conflicts of interest

No conflicts of interest were declared in relation to this paper.

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