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Spatial Distribution and Trends of Waterborne Diseases in Tashkent Province

Veluswami Saravanan Subramanian[1], Min Jung Cho[1], Siwei Zoe Tan[1], Dilorom Fayzieva[2], Christian Sebaly[1]

[1]Department of political and cultural change, Center for Development Research, University of Bonn, Germany; [2]Research Institute of Irrigation and Water Problems, Tashkent, Uzbekistan

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Abstract

Introduction: The cumulative effect of limited investment in public water systems, inadequate public health infrastructure, and gaps in infectious disease prevention increased the incidence of waterborne diseases in Uzbekistan. The objectives of this study were: (1) to spatially analyze the distribution of the diseases in Tashkent Province, (2) to identify the intensity of spatial trends in the province, (3) to identify urban-rural characteristics of the disease distribution, and (4) to identify the differences in disease incidence between pediatric and adult populations of the province.

Methods: Data on four major waterborne diseases and socio-demographics factors were collected in Tashkent Province from 2011 to 2014. Descriptive epidemiological methods and spatial-temporal methods were used to investigate the distribution and trends, and to identify waterborne diseases hotspots and vulnerable population groups in the province.

Results: Hepatitis A and enterobiasis had a high incidence in most of Tashkent Province, with higher incidences in the eastern and western districts. Residents of rural areas, including children, were found to be more vulnerable to the waterborne diseases compared to other populations living in the province.

Conclusions: This pilot study calls for more scientific investigations of waterborne diseases and their effect on public health in the region, which could facilitate targeted public health interventions in vulnerable regions of Uzbekistan.

Keywords: *Spatiotemporal analysis; Environmental health; Tashkent Province; Uzbekistan; Central Asia*

Spatial Distribution and Trends of Waterborne Diseases in Tashkent Province

Veluswami Subramanian Saravanan[1], Minjung Cho[1], Siwei Zoe Tan[1], Dilorom Fayzieva[2], Christian Sebaly[1]

[1]Center for Development Research, University of Bonn, Bonn, Germany;
[2]Research Institute of Irrigation and Water Problems, Tashkent, Uzbekistan

Research

Developing countries with inefficient public health infrastructure, such as those in Central Asia, struggle to address public health challenges[1]. One of the major challenges in the region is access to clean drinking water and sanitation with the urban population having better access to drinking water and sanitation compared to their rural counterparts[2]. Due to a lack of funds dedicated to public health programs, insufficient institutional infrastructure, and inadequate technical expertise, the water utility companies are primarily carrying out emergency repairs rather than renovations, placing the health of Central Asian people at risk. Waterborne diseases caused by microbiological contaminants and pathogens – such as intestinal infections, typhoid[3], intestinal parasites[4, 5], and viral hepatitis[6] – are commonly reported health problems in Central Asian countries[7].

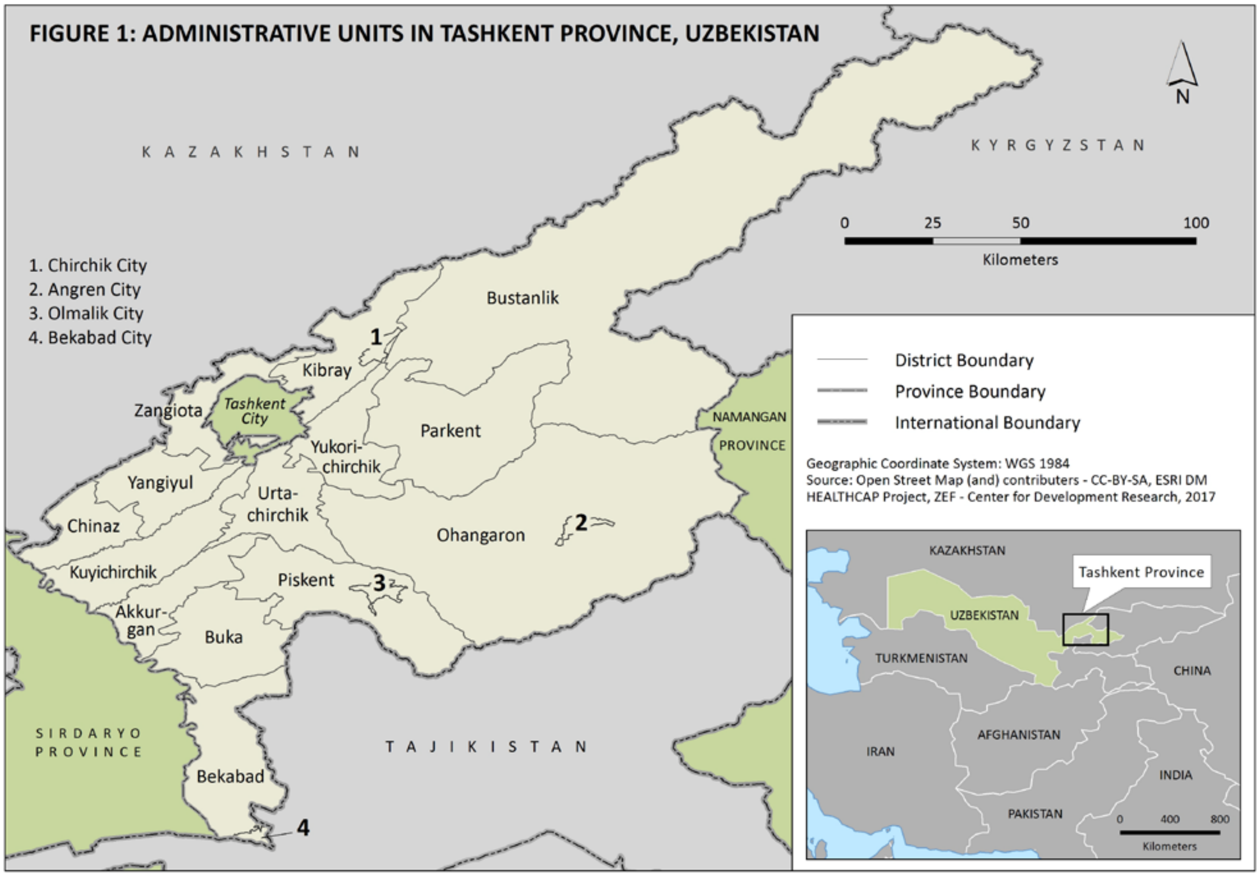

FIGURE 1: ADMINISTRATIVE UNITS IN TASHKENT PROVINCE, UZBEKISTAN

While waterborne diseases are an established health threat in the region, there is a lack of studies that examine the spatial-temporal variation of these conditions[8]. Several published reports suggested the importance of access to safe water supply, environment, and sanitation for children's health in Central Asian countries[4, 9, 10]. The WHO reports that diarrhea is the leading cause of death among children under 5 in this region[9, 11, 12], and this figure ranges from 4-5% in Kazakhstan and Kyrgyzstan to 9-10% in Tajikistan, Turkmenistan, and Uzbekistan[13-17]. Rotavirus infections, which cause severe gastroenteritis in children, lead to the death of 886 children annually in Kazakhstan, Kyrgyzstan, and Uzbekistan, suggesting that 1 in 1153 children in these Central Asian states is vulnerable to rotavirus-related death before the age of 5[10]. Intestinal parasitic infections (including helminths and intestinal protozoa) are also a public health problem that appears to disproportionately affect school-age children[4]. These studies have highlighted issues at the national level[8, 18, 19], but there have been few investigations at the sub-national level, and in particular at the provincial level.

Water quality is a concern in Uzbekistan[20] as over half of the population does not have access to a piped water supply[21] and relies on various sources of water, including outside taps, water pumps in the yard, and public standpipes[19]. The quality of water is further degraded by pollution from domestic waste, organic matter, mineral fertilizers, pesticides, and industrial waste, which has a considerable effect on human health[19, 22]. Furthermore, the industrial sector in Uzbekistan withdraws about 1.2 km^3 of water annually, and almost

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half of this volume is returned as industrial wastewater that poses a serious threat to the quality of drinking water sources[23].

Tashkent Province is in the north-eastern part of the country, between the Syr Darya River and the Tian Shan Mountains. It has an area of 15,300 km², and as of 2014, has a population of 2,644,400 people, which is about 10 % of the total population of Uzbekistan. The province includes five towns (Figure 1) and, excluding Tashkent City, which is governed as an independent administrative unit, is divided into fifteen administrative units called districts. Despite proximity to the capital, only about 82% of the population in the province had access to a piped water supply as of 2005[24], which is a marginal increase from 79% in 2000. Only about 70% of the population had access to sewage systems, septic tanks, or other hygienic sanitation and sewage disposal systems.

This exploratory study utilizes the available social and demographic information to identify hotspots in the distribution of waterborne diseases in Tashkent Province, Uzbekistan. This province was selected for the study due to its proximity to the capital city and due to the accessibility of information. We examined four of the most prevalent waterborne diseases (enterobiasis, acute intestinal infections, hepatitis A, and dysentery) and explored their spatial distributions and trends, focusing on identifying patterns in rural vs. urban populations as well as in pediatric vs. adult cases.

Methods

This paper uses statistical information for Tashkent Province for 2011-2014 to carry out spatial distributions of four waterborne diseases (thematic maps) and to analyze their spatial-temporal trends. The socio-demographic information for the country was based on a sampling of 10% of the population, rather than the traditional census data due to absence of recent census data. The last census was undertaken in 1989 under the Soviet period and results were published in 1990[25]. A census was planned for 2000 but has been postponed due to financial constraints.

The health-related statistical data was obtained from the Republican Centre for Sanitary-Epidemiological Surveillance (CSES) in Tashkent Province. The CSES is a surveillance system that has been in operation since the Soviet period[26], and collects cases of infectious diseases with the help of physicians and healthcare workers in a standardized format that includes basic information about the patients, such as name, age, birthdate, sex, address, primary diagnosis, date of diagnosis, and date of hospitalization[27]. Within 12 hours of diagnosis, all suspected or confirmed cases are reported via telephone (followed up by a written report) to the district (smallest administrative unit, called Tuman) CSES, which is then forwarded to the provincial (called Viloyat) CSES[27].

The district-level socio-demographic information was available for the following categories: total population, children under 14 years of age, and urban and rural classification. These were used to calculate the incidence rates in the province and its urban-rural divisions. The total population of children under 14 years of age was available only for 2014; therefore, the year 2014 was used as a basis to calculate the incidence rates among children.

The district-level CSES obtains additional cases of infectious diseases from clinical, laboratory, and epidemiological information within 24 hours in order to properly respond to a potential outbreak[27]. A separate case report form was prepared by Tuman CSES to summarize the epidemiological work as well as the information collected[27, 28]. The district pools monthly data from both the provincial and national levels[27]. The incidence rates for the urban, rural, and total population were calculated for the districts in Tashkent Province for the years 2011, 2012, 2013, and 2014, and spatially mapped. Pediatric population data were not available for urban and rural populations as separate categories[27].

The base map for Tashkent Province was created using the Open-Street Map[29] and Esri/DeLorme[30]. Using this base map, thematic maps were prepared for each disease to identify spatial-temporal characteristics in their distribution. The districts' yearly incidence rates for 2011 to 2014 were displayed as grouped bar charts, while the average incidence rates of the individual infections are symbolized by the red-color gradation. Those values were generated using the equal interval classification scheme of ArcMap, which divides the given range of attribute values into equal-sized subranges. In order to emphasize the amount of an attribute value relative to other values, four equal-sized classes were created to derive the data from. These four classes were categorized as very high, high, moderate, and low incidences of diseases, with decreasing red intensity indicating lower incidence. The range for these classes varies depending on the attribute values for each specific disease.

Trend surface analysis models the geographic distribution of the average incidence rates throughout space and identifies general tendencies of the sample data[31]. The average incidence rates (Z-axis) were projected as sticks on the coordinate system (X = West to East, Y = South to North) reflecting the location and value (height) of each incidence rate. Two coordinate systems with specific geographic alignments (West-East and South-North, Southwest-Northeast and Southeast-Northwest) were created to identify trends. The polynomial lines drawn through the projected points display the trends in specific directions.

Results

Spatio-temporal trends in waterborne diseases

Of the four waterborne diseases, the incidence rates for enterobiasis were found to be the highest, with a four-year average of about 1084 cases per 100,000 population; and the lowest for dysentery with an average of 28 cases per 100,000 population (Table 1). The spatial-temporal trend revealed a marginal increase in enterobiasis and hepatitis A from 2011 to 2014. Although hepatitis A and enterobiasis incidence rates dropped in 2012, they sharply increased thereafter. Acute intestinal infections decreased since 2011 but increased in 2014. Dysentery was the exception, and its incidence rates have been steadily decreasing since 2011.

	2011	**2012**	**2013**	**2014**
Dysentery	38.23	27.56	23.38	22.30
Hepatitis A	124.34	103.98	147.33	189.68
Acute intestinal infections	201.57	174.31	167.62	173.77
Enterobiasis	1110.22	1018.55	1055.54	1152.01

Source: Republican Center for Epidemiology and Sanitary System (CESS)

Table 1: Average incidence rates (cases per 100,000) of the four major waterborne diseases in Tashkent Province (2011–2014)

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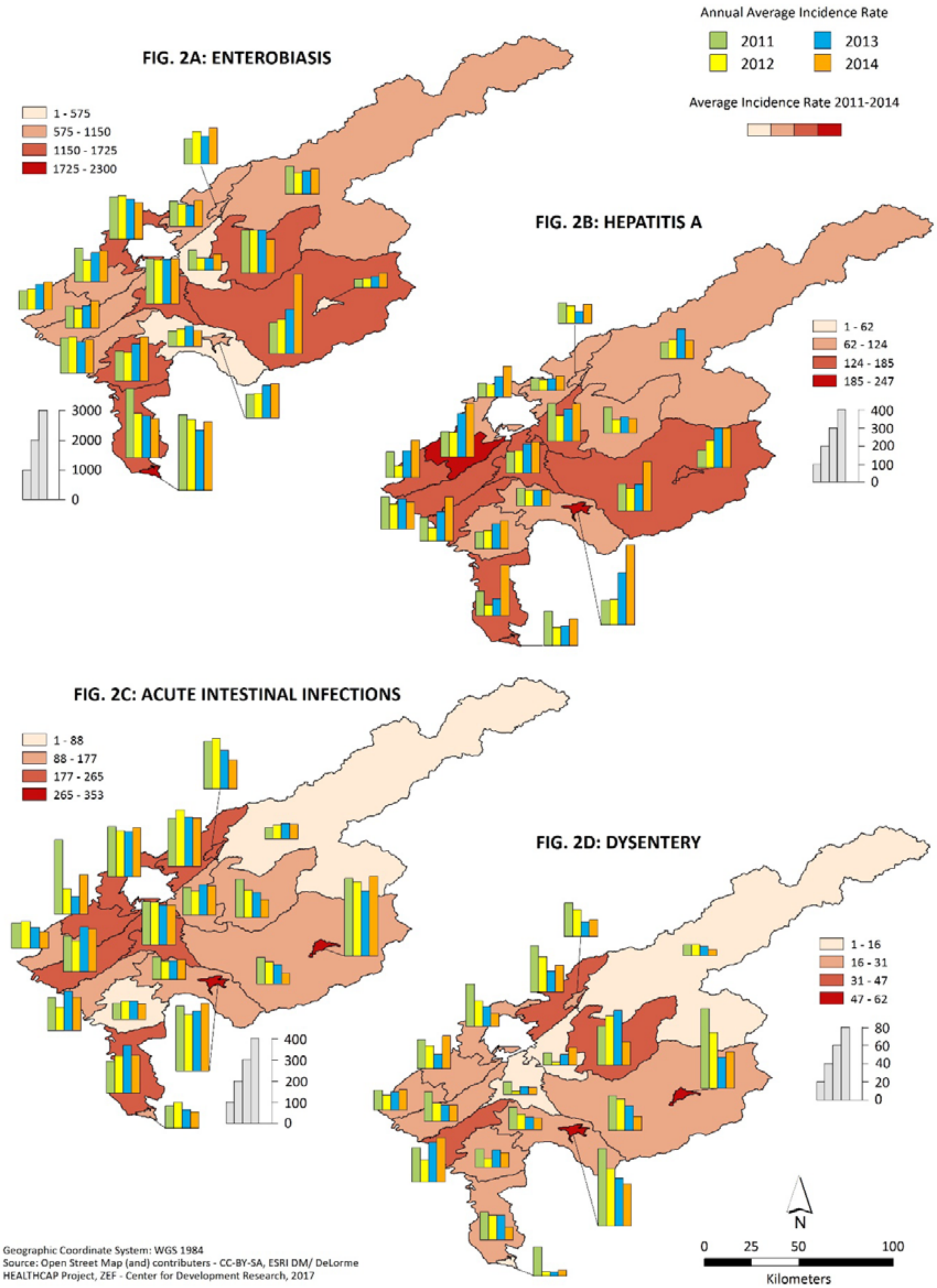
FIGURE 2: SPATIAL DISTRIBUTION OF ANNUAL AVERAGE INCIDENCE RATES OF MAJOR WATER-TRANSMITTED DISEASES IN TASHKENT PROVINCE (2011-2014)



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Spatial distribution of the diseases

The overall spatial distribution of the diseases revealed high incidence rates of enterobiasis and hepatitis A in the central and eastern districts, and of acute intestinal infections and dysentery in the central and western districts of the province (Figure 2). Enterobiasis appeared to be spatially focused in the eastern and southern parts of the province (Figure 2a). Bekabad City had the highest average incidence rates, about six times higher than the district and twice that of the total average for Tashkent Province. A high incidence of hepatitis A (more than 185 cases) was reported in Yangiyul District and Olmalik City (Figure 2b). A moderate incidence (62 to 124 incidence rates) of hepatitis A was reported in the central districts of the province. Acute intestinal infections were reported to be high in Angren City and Olmalik City (Figure 2c). Dysentery showed a decreasing trend across the province and has the lowest incidence rates of the four diseases in this study (Figure 2d). The highest average incidence rates for the 2011–2014 period were found in Olmalik City and Angren City, while the lowest rates were found in Urtachirchik, Bustanlik, and Bekabad City.

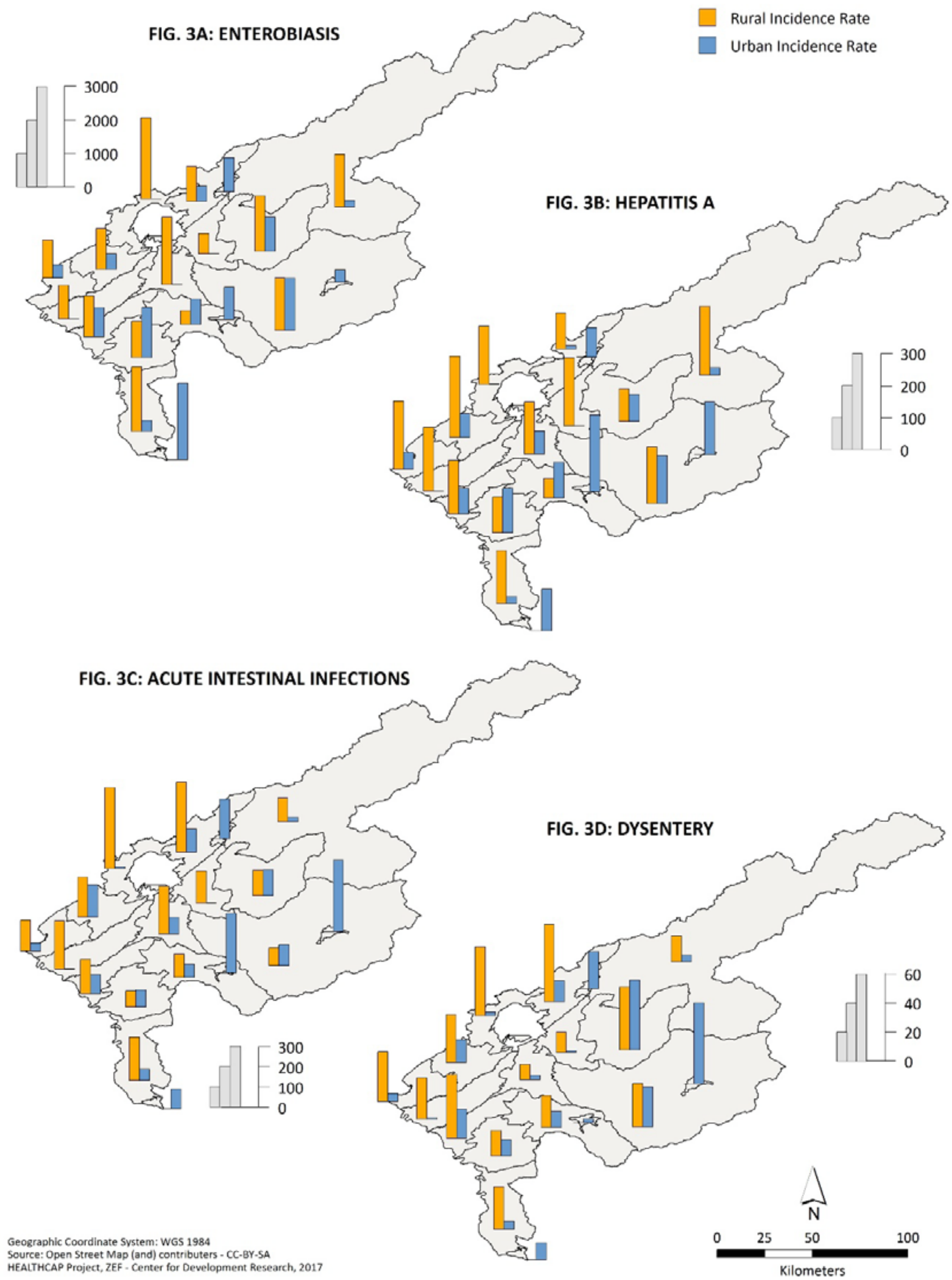
Spatio-temporal trends in the incidence

Spatio-temporal trends in the incidence of diseases revealed increasing trends of enterobiasis in the east (Figure 2). Hepatitis A revealed an increasing trend among eastern and western districts. Acute intestinal infections remained stable, while dysentery showed a decreasing trend across the province. An increasing trend in the incidence of enterobiasis was found in Ohangaron District, and in Buka, Chirchik City, and Olmalik City (Figure 2a). Hepatitis A incidence rates were increasing across the province (Figure 2b), but spatially focused in the southern and eastern parts of Tashkent Province. Olmalik City and Yangiyul District could be considered as hotspots, as the trend of increasing incidence was strongest there, along with Bekabad District. Only districts Parkent and Kuyichirchik and two cities, Bekabad and Chirchik showed a decreasing trend. For acute intestinal infections, a decreasing trend was observed in the majority of the districts (Figure 2c). However, an increasing trend was observed in Angren City, Olmalik City, and Bekabad District, and in the two northwestern districts of Yangiyul and Zangiota. The spatial trends for dysentery were closely related to those for acute intestinal infections, although its incidence rates were much lower (Figure 2d). There was an overall decreasing trend; however, several districts in the western part of the province registered a slight increase in total incidence rates. The trend surface analysis for 2011–2014 demonstrated two sets of diseases presenting two different geographical trends (Appendix 2). The disease that showed strongest spatial variation was enterobiasis, which was concentrated towards the east, southeast, and southwest. Hepatitis A incidence also showed a spatial concentration towards the center and east, and tends towards southeast and southwest. Overall, the trend surface analyses revealed the east, southeast, and southwest as hotspots vulnerable to enterobiasis and hepatitis A. In contrast, the center and southeast regions were vulnerable to dysentery and acute intestinal infections.

Urban and rural distribution

All four major waterborne diseases had higher incidence rates in the rural areas of the province compared to the urban areas during 2011–2014. The urban-rural gap was more than 50% for enterobiasis and hepatitis A, followed by acute intestinal infections. Dysentery was reported to have the lowest urban-rural gap in its incidence rates. Enterobiasis had higher average incidence (rates of more than 1500 per 100,000) in rural regions and in Bekabad City during the four-year period (Figure 3a). A higher incidence rate (more than 150 per 100,000) of hepatitis A was reported across ten districts and in two cities (Olmalik and Angren) in the province (Figure 3b).

FIGURE 3: SPATIAL DISTRIBUTION OF AVERAGE URBAN AND RURAL INCIDENCE RATES OF MAJOR WATER-TRANSMITTED DISEASES IN TASHKENT PROVINCE (2011-2014)



While acute intestinal infections were more dominant in the rural areas, the urban areas were comparable in terms of incidence rates (Figure 3c). Dysentery was more common (more than 40 cases) in the districts where higher rates of acute intestinal infections were reported (Figure 3d).

Distribution of disease among children

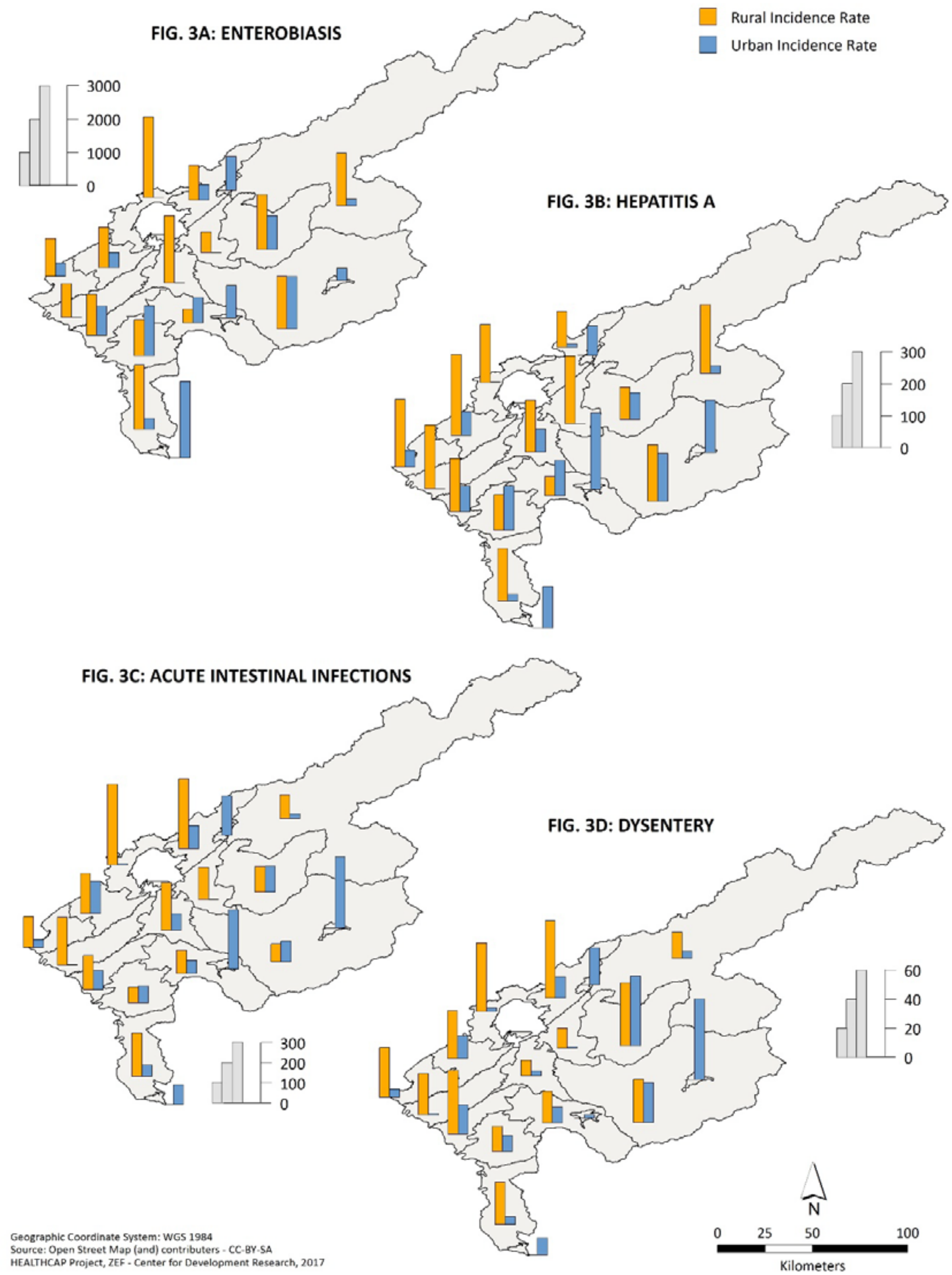
Children were found to be more vulnerable to these diseases compared to the adult population. The average incidence rates among children under 14 years of age were more than double the incidence rates among the adult population in the province in 2014, with enterobiasis more than three times more common than in the adult population. In a few selected districts the spatial distribution revealed a wider gap between children under 14 years of age and the adult population in the incidence of enterobiasis (Figure 4a). For hepatitis A, a persistent and large gap between incidence in the adult population and among children was found across the province (Figure 4b). A higher incidence in acute intestinal infections among children under 14 years of age was reported in Angren and Olmalik cities, and in Kibray and Zangiota districts (Figure 4c). In the case of dysentery, a reduced difference was observable across the province, except in Angren and Olmalik cities, and Parkent district (Figure 4d). The temporal trends among children under 14 years of age for 2011–2014 were higher in Angren and Olmalik cities, and Ohangaron, Bekabad, and Zangiota districts. The incidence rates of enterobiasis among children significantly increased in Ohangaron and Buka districts, while Bekabad City reported a stable high incidence rate across the four years. Hepatitis A showed an increasing trend in Olmalik and Angren cities, and Yangiyul, Bekabad, and Ohangaron districts. Interestingly, a decrease was seen in Bustanlik district. There was an increasing trend of acute intestinal infections in Zangiota, Bekabad, and Kuyichirchik districts, while Angren and Olmalik cities and Kibray and Zangiota districts reported high but stable incidence across the four years. Dysentery showed a decreasing trend across the province, except in Akkurgan district.

Discussion

The findings of this analysis revealed that hepatitis A and enterobiasis had high incidence rate in most of Tashkent Province, with both diseases sharing similar characteristics: they were transmitted through the fecal-oral route and were more prevalent in the younger populations. People living in rural areas, including children, were found to be more vulnerable to the waterborne diseases compared to the more urban population. A persistent rural bias was reported for all four of the waterborne diseases.

Among the districts, Akkurgan and Zangiota were vulnerable to all four diseases in rural areas. The districts of Bekabad, Ohangaron, Kuyichirchik, and Urtachirchik had vulnerability to enterobiasis and hepatitis A, and the Kibray and Parkent districts were vulnerable to acute intestinal infections and dysentery. The average rural incidence rates of enterobiasis and hepatitis A were twice as high as in urban areas. Among the cities, Olmalik and Angren could be considered as hotspots for increased incidence rates of the waterborne diseases. Bustanlik and Bekabad showed considerable difference in the distribution of enterobiasis incidence rates between urban and rural sectors, but it is unclear if the low urban incidence rates reflected the level of urban population density or whether the urban areas in these two districts had better access to healthcare. Another example were the districts that reported higher rural incidence rates, such as Yangiyul. Interestingly, Piskent and Buka both showed higher urban incidence rates for enterobiasis and hepatitis A compared rural incidence rates. There are several plausible explanations of why the disease incidence is higher in rural areas worthy of further investigation. One explanation could be a growing gap in healthcare access between the urban and rural areas, with a growing population residing in rural areas.

FIGURE 3: SPATIAL DISTRIBUTION OF AVERAGE URBAN AND RURAL INCIDENCE RATES OF MAJOR WATER-TRANSMITTED DISEASES IN TASHKENT PROVINCE (2011-2014)



This study demonstrated that children are more vulnerable in the province. This is consistent with other studies[32], which reported over 70% of observed cases involving children under 14 years of age, and also with the reports from Fayzieva[33] and Alimova and Fayzieva[24] which also identified the districts of Yangiyul, Akkurgan, Kuyichirchik, and Urtachirchik in Tashkent Province as being at high risk for waterborne diseases. These hotspots require further investigation to understand the causes and epidemiological characteristics of the diseases.

Bekabad District is an area with a significant industrial presence, where mining, pulp mills, and tanneries discharge toxic waste[24]. Yangiyul District is at the receiving end of the wastewater discharged from Tashkent City. In many cases, wastewater from these industries not only drains directly into rivers but also seeps into the ground, contaminating aquifers and wells[34]. Improper treatment of industrial and municipal wastewater may explain adverse health events among residents of Olmalik and Angren cities, as well as Bekabad and Yangiyul districts. While these studies suggest poor quality of water in the water systems, it is difficult to establish a link without appropriate information on water quality and adequate information on the socio-demographic and health parameters.

This study may suggest that existing water quality monitoring system and its analysis of microbial indices are potentially insufficient to prevent infectious disease outbreaks. These are complex issues requiring a resolution[35]. In most low-income countries, the problem arises from the lack of separation of water sources used in agriculture irrigation and industrial wastewater management [35]. This also applies to Uzbekistan, as its insufficient regulations of industrial pollution control and wastewater agricultural usage increased the risk of microbiological contamination of surface water and groundwater, and the transfer of chemical and biological contaminants to crops, ultimately affecting public health [35].

The CSES plays a major role in environmental health, food safety, and control of communicable diseases in the Central Asian region. In the case of Uzbekistan, CSES plays a crucial role in health protection with its extensive infrastructure and network within the nation. Yet, the effectiveness of this system is not well known due to lack of external evaluation[36, 34]. There is a potential for low reliability of the data collected through this system due to several factors such as lack of qualified medical personnel and lack of inadequate laboratory resources as pointed out by other studies done in the Central Asian region[27, 28, 37]. Gradual steps need to be taken to improve ways of administration and management of CSES, which would open possibilities to focus on learning international methods and practices. Another option to help evaluating its adequacy and relevance for policy making is to make public information such as socio-demographic statistics accessible to general population.

The findings of this study can help to underline the potential of CSES's existing capacities and recommend ways for advancing practice. While national and international studies have highlighted the importance of investigating environmental health issues at the national level[18, 19, 33, 34], little has been done on the local level. This study helps to fill this gap. Across the province, these diseases were more prevalent in rural areas compared to urban regions. The most vulnerable districts were Ohangaron, Urtachirchik, Bekabad, Kibray, and Zangiota, while among the cities, Olmalik and Angren reported high incidence rates. Children under 14 years of age were found to be twice as vulnerable to waterborne diseases as compared to the adult population. These findings are only exploratory, but highlight the importance of improving our scientific understanding of public health challenges in the region. Given the scarcity of literature and the lack of accurate etiological data on the four diseases in Tashkent Province, this paper can serve as a foundation for developing more in-depth epidemiological studies and providing targeted interventions for vulnerable regions and populations [27, 38]. Corroborating previous studies[37, 39], our findings suggest the need for a long term commitment, collaborative efforts with international partners, as well as political will from the local authorities, in order to advance the development of a modern infectious disease surveillance system in Uzbekistan.

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