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Geospatial Analysis of Water-related Diseases in Tashkent Province

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Geospatial Analysis of Water-related Diseases in Tashkent Province

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Abstract

The impact of water quality on human health is an increasingly important issue. The inadequate access to clean drinking water is one of the leading causes of intestinal infections. Unhygienic living conditions represent another risk factor. Only 83.8% of the Uzbek population has access to piped water, and this coverage sinks to 78.5% for rural areas. The rural population usually uses open sources such as '*aryks'*, water reservoirs, rivers and channels for potable needs. But, the water quality of these sources has significantly deteriorated, especially in the downstream areas of the river basins. Periodic droughts causing deterioration in the sanitary and epidemiological situation are an additional risk factor. Under hot climatic conditions, water consumption increases, and toxic effects of harmful substances in drinking water has substantial impact on human health. Due to climate change and global warming, this trend is likely to intensify. Tashkent province was selected as the research area for this study. The province consists of 15 administrative districts and became one of the highly densely populated in comparison with other provinces in Uzbekistan. The paper examines the spatial distribution of water-borne diseases in Tashkent province. The study was based on data collected and provided by the sanitary-epidemiologic supervision center of Tashkent province. Morbidity rates of the population with acute intestinal infections and bacterial dysentery were obtained for the period 2006-2010. The data was subject to spatial analysis using ArcView GIS.

Keywords: Uzbekistan, water quality, spatial distribution, water-borne diseases

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1 Introduction

Safe drinking water is an important issue for Uzbekistan and the Central Asian region. Despite the fact that the coverage with drinking water in the country increased by about 1.5 times during the last five years, the problem of access to 'safe' water remains very urgent, Water supply coverage in Uzbekistan averages 83.8%, and drops to 78.5% in its rural areas. The rural population throughout the Uzbek Republic often resort to using '*aryks*', water reservoirs, rivers, and channels as potable water sources, and domestic water quality significantly deteriorates in the downstream areas of the rivers (Herbst 2006, Fayzieva et al. 2008). These contribute to villagers getting sick more often than their urban counterparts (Herbst 2006).

Water supply is important for the maintenance of proper sanitation and personal hygiene; inadequate water supply increases the risks of diarrhea and other infectious diseases. Waterborne diseases are caused by pathogens spread through contaminated drinking water or recreational water (Craun 1986). In developing countries, the magnitude of fecal pollution of drinking water and the incidence of waterborne disease is much higher than in industrialized countries, and this is especially so in rural areas (WHO 2006). There are many routes of exposure, as well as individual or population susceptibility, to waterborne pathogens, with water quality, availability, sanitation, and hygiene all playing a role (Frost et al. 1996). There are complex relationships between human health and water quality, water quantity, sanitation and hygiene. Also, changes in surface water quality and quantity are likely to affect the incidence of diarrheal diseases (Lipp and Rose 1997).

The prevalence of water-borne intestinal infections may also be due to anthropogenic impacts on water sources, which cause bacterial contamination and create favorable conditions for the growth and multiplication of pathogens, especially in summer (Fayzieva 2000). One significant factor are the conditions of water supply, such as access or the lack of access to piped water and the sanitary-bacteriologic state of reservoirs used by population for household needs and drinking (Fayzieva 2000). Active diarrheal surveillance over almost 10 weeks, carried out in Nukus city of Karakalpakstan in Uzbekistan, revealed a mean monthly diarrheal rate of 75.5/1000 among individuals with piped water on their premises and 179.2/1000 among those without piped water on the premises (Semenza 1998). Chemical contamination is another serious environmental problem. Together, contamination of water adversely affects the health, mortality, and infection morbidity of the population (Iskandarova 1999).

In all regions of Uzbekistan, the peak incidence for acute intestinal infection is recorded during the warm period of the year, from May to October or November, and children are the most vulnerable group. Periodic droughts causing deterioration of the sanitary and epidemiological situation are an additional risk factor. Under hot climatic conditions, the toxic effect of harmful substances contained in drinking water increases, as well as the epidemiological role of water sources with low quality water. But water consumption increases as well. Due to climate change and warming, this trend is likely to persist. The first detectable changes in human health resulting from climate change may well be alterations in the geographic range (latitude and altitude) and seasonality of certain infectious diseases – including vector-borne infections such as malaria and dengue fever – and water- and food-borne infections (e.g. acute intestinal infections, salmonellosis) which peak in the warmer months. Warmer average temperatures combined with increased climatic variability would alter the pattern of exposure to temperature extremes, in both summer and winter, and their resultant health impacts. Drinking water is known to be a vehicle for fecal-oral disease transmission (WHO 2006). Waterborne diseases occur due to the ingestion of drinking water contaminated with bacteria, viruses or protozoa. Among the classical waterborne diseases are diarrheal diseases, typhoid fever (*Salmonella typhi*), amoebic dysentery (*Entamoeba*

hystolitica), and bacterial dysentery or shigellosis (*Shigella spp.*). Other diseases also known to be waterborne include hepatitis A and E. The microbiological causes of diarrhea linked to contaminated water supplies are: cholera, cryptosporidium, E.coli, giardia, shigella, typhoid, and viruses such as hepatitis A (WHO 2006). This group of infectious diseases saw high incidence rates during the last years, and the transmission via water is considered to be one of the significant causes. The wide spread of acute enteric infections is a social and economic problem in the Central Asian region.

Climatic events caused by climate change pose a challenge for public health. Most observed associations between climate and water-borne diseases are based on indirect evidence of seasonal variations. However, several studies provide quantitative evidence of water-borne diseases' links to climatic factors such as precipitation and ambient air temperature. Outbreaks of cryptosporidiosis, giardia, leptospirosis and other infections have been shown to be associated with heavy rainfall events, even in countries with a regulated public water supply (Atherton et al. 1995). A study of waterborne disease outbreaks in the United States has also shown that about half the cases were significantly associated with extreme rainfall (Curriero et al. 2001). An association between drinking water turbidity and gastrointestinal illness has been reported by Schwartz and Levin (1999), who used a time series in their analysis. Other studies point out the physical mechanisms through which climatic conditions influence the incidence of water-borne diseases. Heavy rainfall events can transport terrestrial microbiological agents into drinking-water sources, thereby contaminating watersheds with human and animal fecal products and other wastes in the groundwater, and result in outbreaks of infections (Lisle and Rose 1995, Atherholt et al. 1998, Rose 2000, Curriero et al. 2001). Evidence of water contamination following heavy rains has been documented for cryptosporidium, giardia, and E.coli (Parmenter et al. 1999, Atherholt et al. 1998). Water treatment plants may have to shut down because of water turbidity resulting from heavy precipitation (Huang et al. 2011). The incidence of waterborne diseases may be increased in conditions of high soil saturation due to more efficient microbial transport (Rose et al 2001). At the other extreme, water shortages in developing countries have been associated with increases in diarrheal disease outbreaks that are likely attributed to improper hygiene (WHO 2006).

Another mechanism through which climate change exerts health impacts is via the projected increase in temperatures. Transmission of enteric diseases may be increased by high temperatures, which favor the growth of disease organisms in the environment (Bentham and Langford 2001, Madico et al. 1997). In 1997 a markedly greater number of patients with diarrhea and dehydration were admitted to a rehydration unit in Lima, Peru, when temperatures were higher than normal during an El Niño event (Salazar-Lindo 1997). A time series analysis of daily data from the hospital confirmed an effect of temperature on diarrhea admissions, with an estimated 8% increase in admissions per 1°C increase in temperature (Checkley 2000).

Thus, human exposure to water-borne infections can occur as a result of contact with contaminated drinking water, recreational water, coastal water, or food. Exposure may be a consequence of human processes (improper disposal of sewage wastes) or weather events. Rainfall patterns can influence the transport and dissemination of infectious agents while temperature can affect their growth and survival (Rose et al. 2001). Increasing temperatures may lengthen the seasonality or alter the geographical distribution of water-borne diseases (Epstein 1999). Research investigating possible links between temporal and spatial variation of climate and the transmission of infectious diseases can be broadly categorized into three areas:

1. Evidence for associations between short-term climate variability and infectious disease occurrence in the recent past.
2. Evidence for long-term trends of climate change and infectious disease prevalence.

3. Evidence from climate and infectious disease linkages used to create predictive models for estimating the future burden of infectious disease under projected climatic conditions

The problems of ecological and epidemiological characteristics of intestinal infections are rather urgent, due to environmental and climate peculiarities, the specific modes of water consumption, and the anthropogenic pressure on water sources in this region (Fayzieva et al. 2001, Iskandarova 1997). However, there is a lack of studies in Uzbekistan. It is necessary to carry out in-depth research using modern approaches of multidisciplinary examination of the cause-effect relationship at the ecosystem level, with better methods of laboratory analysis taking into consideration all possible epidemiological links in the process. It would be very useful to study not only characteristics of the infectious agents and the human body, but also the character and impact of the environment. This, in turn, would allow a proper evaluation of the ecological and epidemiological situation in the region, which could form the scientific basis for decision-making in order to prevent appearance of infectious diseases through the elaboration of targeted preventive measures (Fayzieva 2000).

2. Analyzing population health using GIS

Geographical information systems (GIS) have a significant role to play in health research, whether through the description and explanation of spatial variation of disease and illness, or the planning and use of health services (Gatrell & Senior 2005). Anselin and Getis (1991) argue that GIS have proven their usefulness through a wide variety of applications, due to their ability to store and combine spatial data from different sources in a structured manner, perform various manipulations, and present the resulting information in the form of maps. Many organisations and institutes working at various scales collect spatially-related data for planning and policy purposes and increasingly make use of GIS to store and process this data. GIS have been successfully implemented for planning, maintenance and monitoring of spatial objects. Interest in GIS in the scientific field, particularly its use as an instrument for supporting spatial research and regional studies, has thus been increasing. In terms of confirmatory statistical analysis within a GIS environment, not much has been achieved. Most of the applications are non-spatial applications of regression analysis and fail to exploit the information on the topology of the observations that is contained in a GIS. A significant discrepancy between GIS as an instrument for processing spatial data, and the need for exploratory analytical techniques linked to or implemented in GIS, has come to the fore.

GIS have proven to be one of the most useful tools in public health research. It has been widely used in disease surveillance and monitoring, research hypotheses generation, identification of high-risk areas and populations, targeting resources, and the monitoring of interventions (Gupta et al. 2003). GIS provides an effective tool for visualization and spatial analysis of epidemiological data and environmental exposure. Recent studies have shown the increasing use of GIS as an important component in public health and epidemiology (Gupta et al. 2003). An important issue in disease-mapping – besides scale and classification – is the way in which data is spatially represented. The geographical distribution of a disease, particularly the determination of areas with extreme data values, might give more insight in the etiology of the disease. Brown (1990) noted that “some interesting spatial health studies in a GIS environment have been conducted on mapping and analyzing the probability of extreme values.” It is vital to introduce and apply new information technologies for improving water quality management and preventing waterborne diseases. GIS techniques offer special benefits in this respect by helping to provide more integrated information on climate, water quality and health, thereby facilitating collection of data from the many different organizations and institutions involved in the management and monitoring – including those responsible for hydrometeorology, water supply, monitoring, and protection of water resources. One of

the opportunities offered by GIS is assessment of water quality impact on population health under the certain environmental conditions.

A group of researchers (Fayzieva et al.2002, 2008) evaluated in the period of 2000—2007 the potential risks of water-borne infections incidence using GIS in one of the most densely populated regions of Central Asia – the Samarkand and Navoi provinces situated in the Zaravshan River basin – where high rates of water-borne infections such as typhoid fever and bacterial dysentery were observed. The study sought to: summarise the data on physical, geographic and socio-demographic factors influencing condition of the water reservoirs; evaluate anthropogenic pollution affecting the reservoirs used for drinking water; analyse the health status of the population in terms of the incidence of water-borne diseases; and evaluate the effectiveness of preventive actions aimed at assuring water quality standards and protecting human health. The study was based on data provided by the agencies responsible for environmental protection, environmental monitoring, and environmental health (known in Uzbekistan as sanitary-epidemiological supervision). Water quality indicators and morbidity rates of the population with water-borne diseases (typhoid fever, bacterial dysentery, other diarrhoeal diseases and viral hepatitis A) were available for the period 1996—2005 and the spatial analysis was performed with ArcView GIS. The results revealed that intestinal infections, including typhoid fever, in the Zaravshan River Basin is not scattered but rather high morbidity rates were focused in certain local areas associated with specific water conditions. Especially high rates were observed in the settlements located in the areas with high levels of anthropogenic pollution (Fayzieva et. al. 2002, 2008).

2.1 Geo-spatial analysis of water-related diseases in Tashkent Province

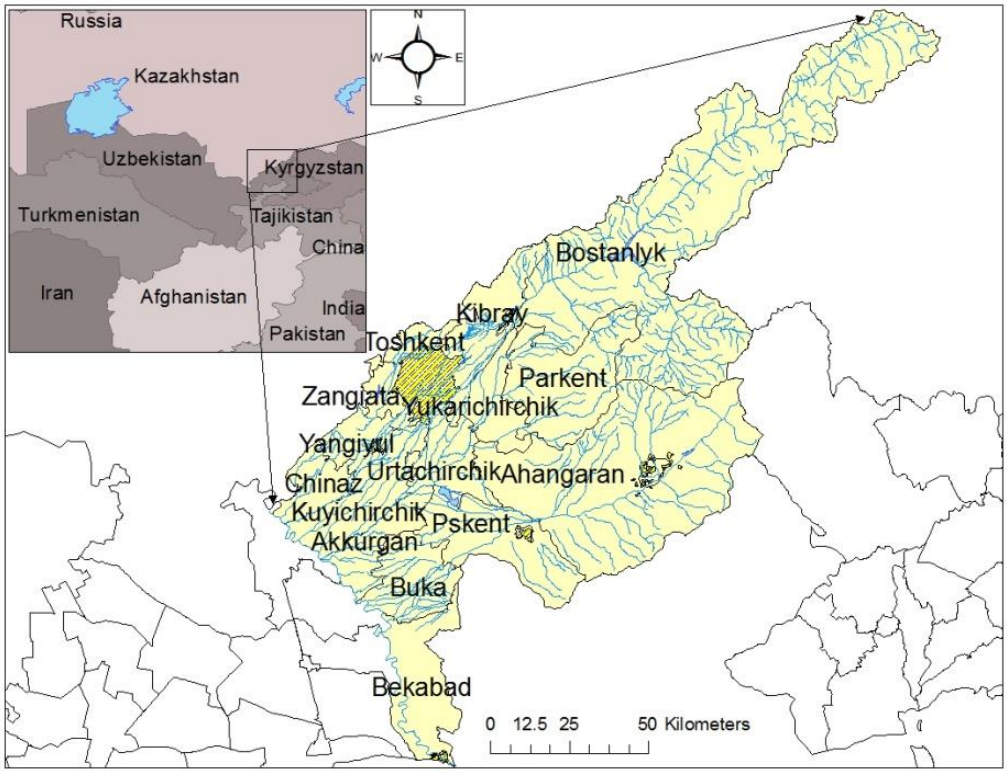
The province of Tashkent is located in the northeastern part of Uzbekistan, between the Syr-Darya river and the Tien Shan mountains. It shares international borders with Kyrgyzstan and Tajikistan, and provincial borders with Sirdarya and Namangan. It covers an area of 15,300 km². The population is estimated to be around 2,250,000. Tashkent province comprises 15 administrative districts. The capital city of the same name, Toshkent (Tashkent), has an estimated population of 2,200,000 inhabitants, and is governed separate from the province as an independent administrative unit.

The climate of the province is moderately continental with vertical zonation. It experiences high daily and annual fluctuation in air temperatures and uneven quantities of precipitation both across a year and across a series of years. Tashkent province comprises two main mountain climatic zones:

- Mountain zone with sub-nival and damp climate – the mountain belt in altitude between 1,500-3,000 meters, characterised by low temperatures and high precipitation in comparison with the valley areas.
- Foothills and intermountain areas characterised by arid climate and deficit of water in the summer period.

Monthly data for two waterborne diseases (acute intestinal infections and bacterial dysentery) in the five towns and 15 districts were obtained from the Ministry of Health of the Republic of Uzbekistan for the five-year period 2006—2010. An appropriate database was created for each part of the study. Finally, all data was entered into the GIS database.

Figure 1. Map of Tashkent Province with districts

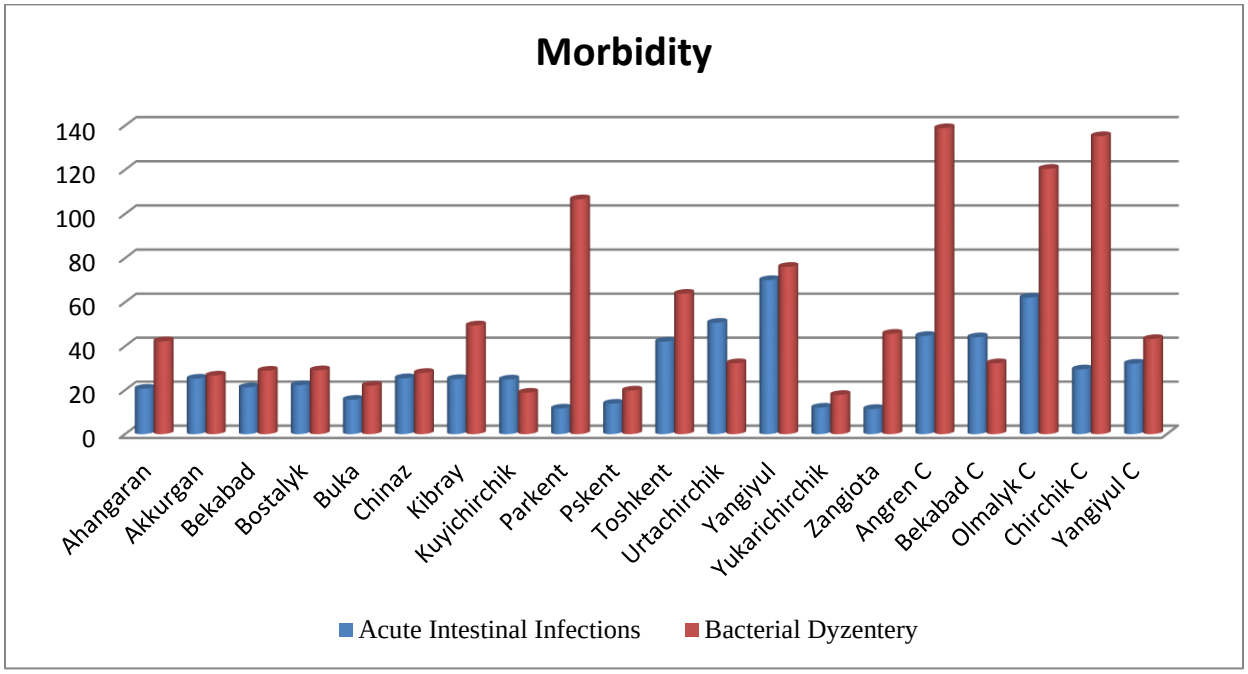


Source: RISHOD

Figure 2 shows the distribution of average morbidity rates of acute intestinal infections and bacterial dysentery in the districts and towns of Tashkent province. In the majority of the districts and towns, morbidity rates of bacterial dysentery are higher relative to that of acute intestinal infections. In Parkent, and the towns of Angren, Olmalyk and Chirchik, morbidity of bacterial dysentery is at least twice (Olmalyk) to ten times higher (Parkent). Although acute intestinal infections morbidity rates are generally lower, they are significantly higher in Olmalyk town, Yangiyul and Urtachirchik.

Maps of these two waterborne diseases in Tashkent province were then created to conduct spatio-temporal analyses of the distribution of the diseases. Figures 3.1 to 3.5 show the annual progression of the spatial distribution of morbidity rates of acute intestinal infections from 2006 to 2010. The eastern part of the province, excluding the towns of Olmalyk and Angren, stayed consistently low risk until 2010. The disease appeared to be concentrated in the western part of the province, around the districts of Yangiyul, Urtachirchik, and Akkurgan. More cases were registered in Urtachirchik and Akkurgan districts in 2007. From 2008 to 2010, high morbidity rates of acute intestinal infections were found in Yangiyul district. It can be concluded that Yangiyul district is a hotspot and the area most vulnerable to acute intestinal infections. This could be explained by its geographical position: Yangiyul district is located downstream of the Chirchik River basin. This district accepts urban sewerage waters from Tashkent city, which is discharged into the canal Salar after biological treatment. But this treatment plant was constructed at the beginning of the 1970s and has an operational efficiency of around 55-65%.

Figure 2: Average morbidity rate of waterborne diseases in districts and towns of Tashkent province from 2006 to 2010.



Source: Authors

Figure 3: Distribution of acute intestinal infections in Tashkent province, 2006—2010

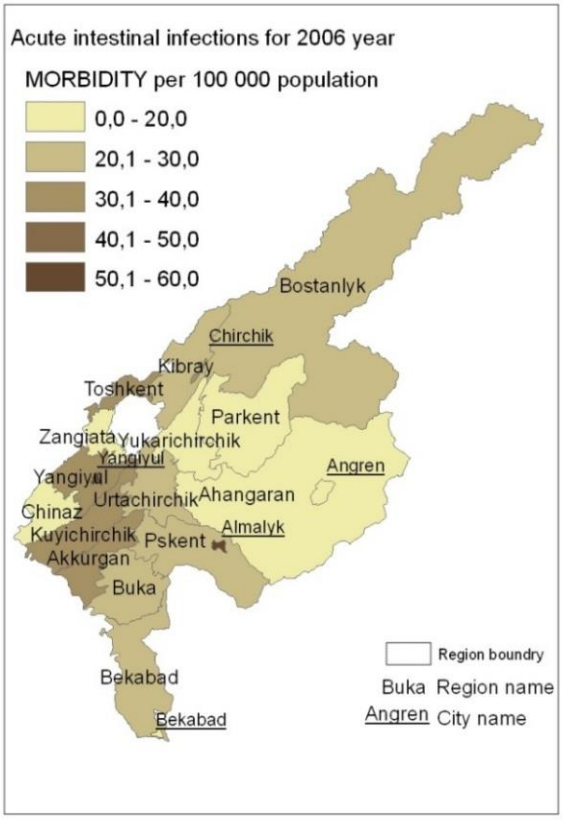


Figure 3.2: Distribution of acute intestinal infections in Tashkent province, 2007

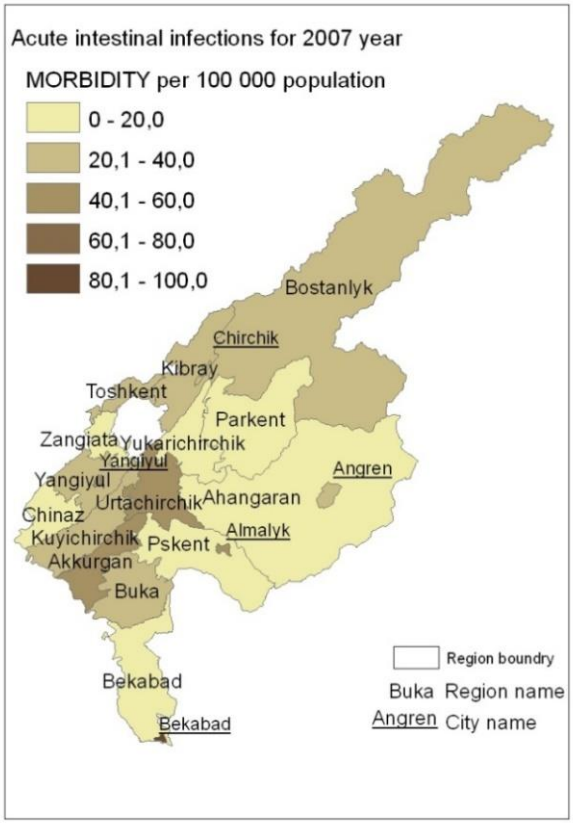


Figure 3.3: Distribution of acute intestinal infections in Tashkent province, 2008

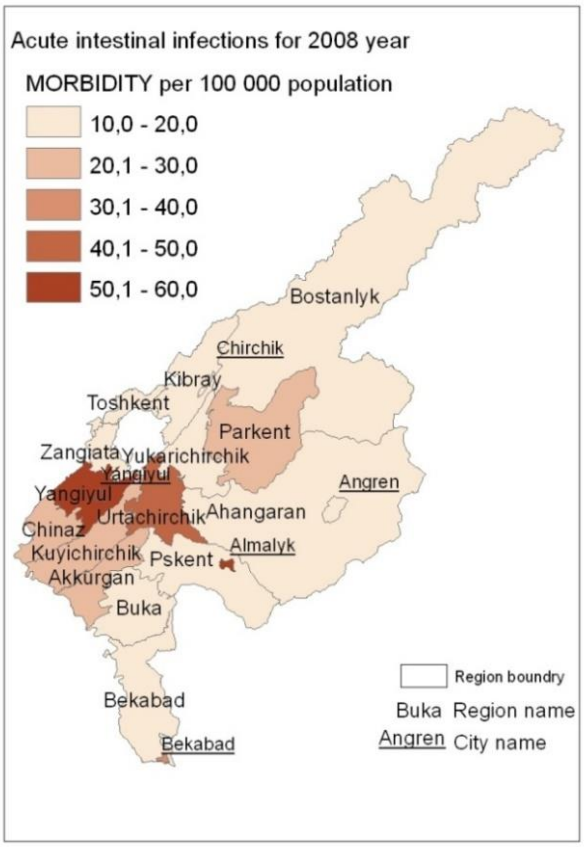


Figure 3.4: Distribution of acute intestinal infections in Tashkent province, 2009

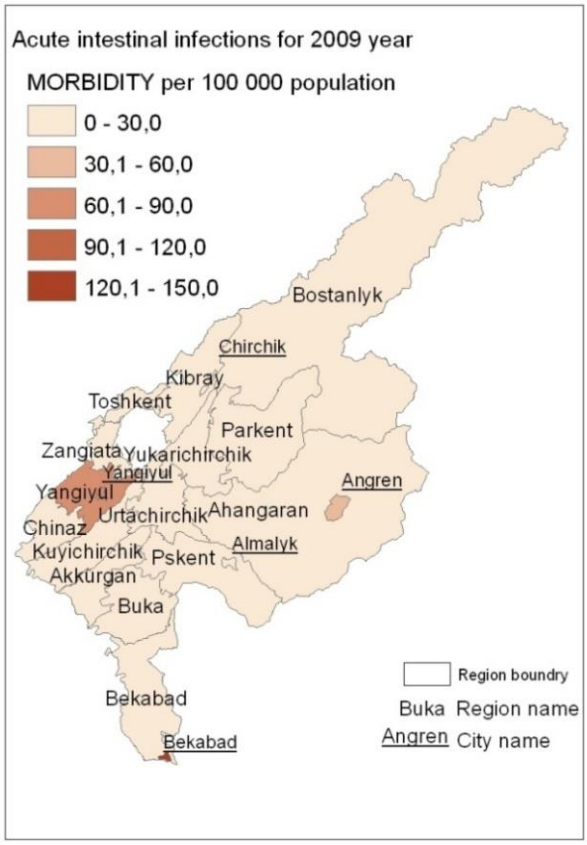
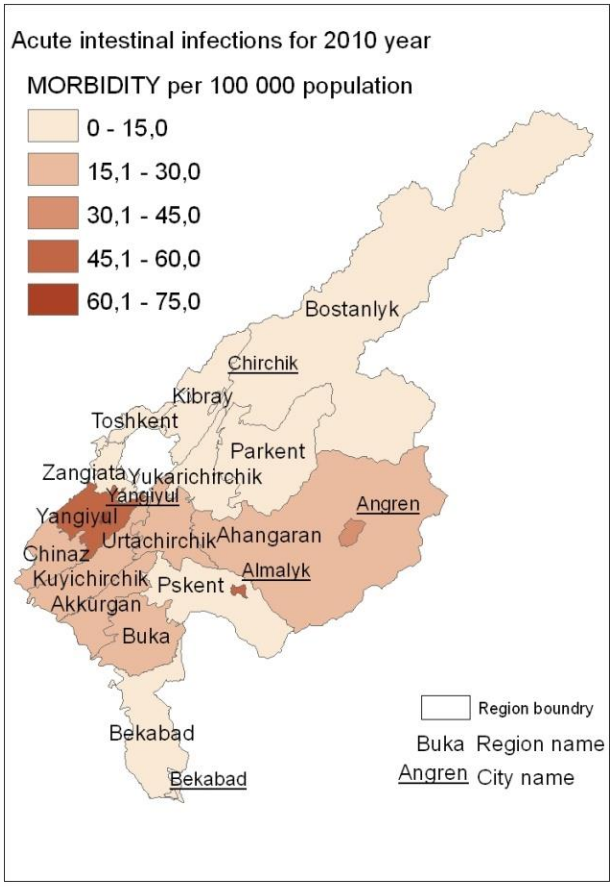


Figure 3.5: Distribution of acute intestinal infections in Tashkent province, 2010



Source: RISHOD

Figure 4: Distribution of bacterial dysentery in Tashkent province, 2006-2010

Figure 4.1: Distribution of bacterial dysentery in Tashkent province, 2006

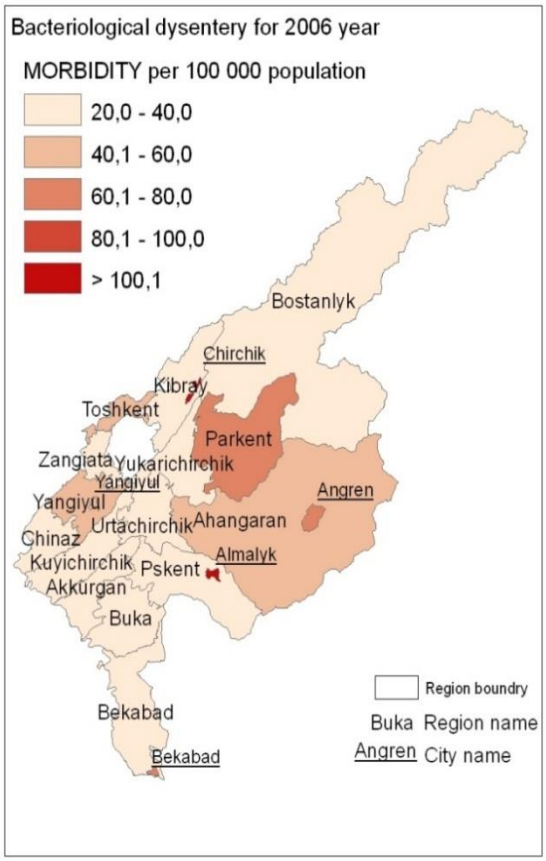


Figure 4.2: Distribution of bacterial dysentery in Tashkent province, 2007

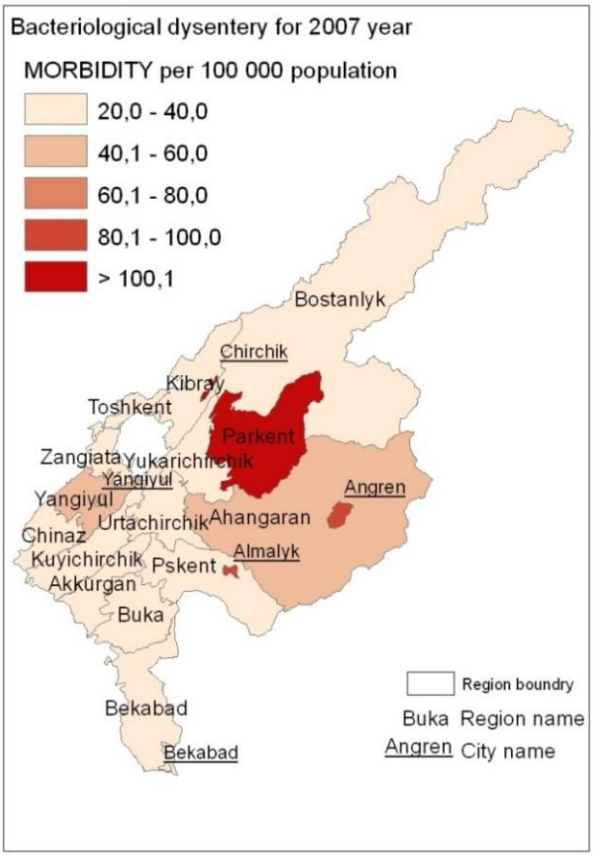


Figure 4.3: Distribution of bacterial dysentery in Tashkent province, 2008

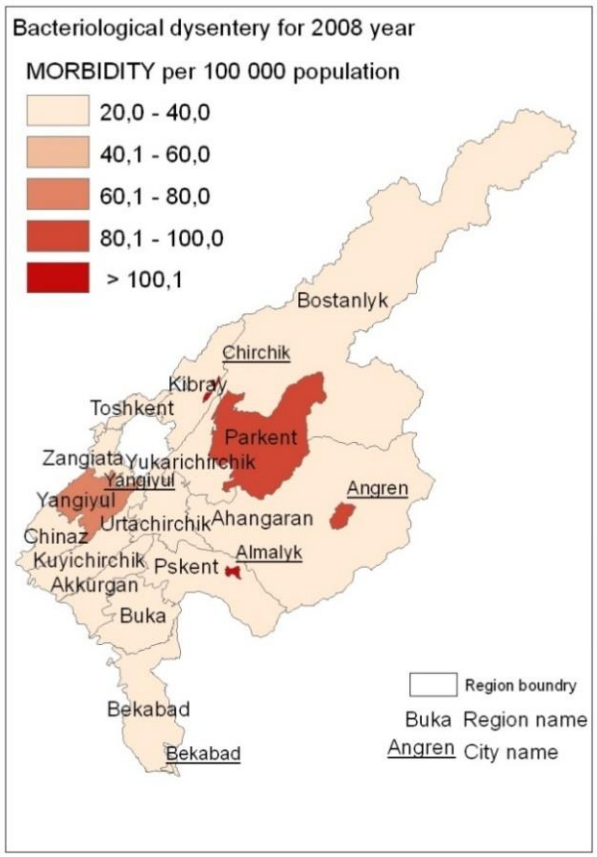


Figure 4.4: Distribution of bacterial dysentery in Tashkent province, 2009

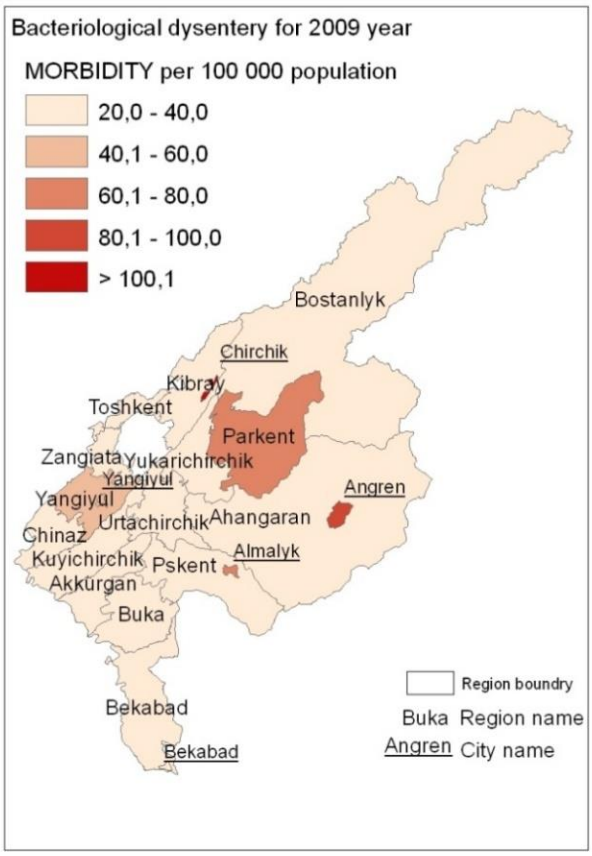
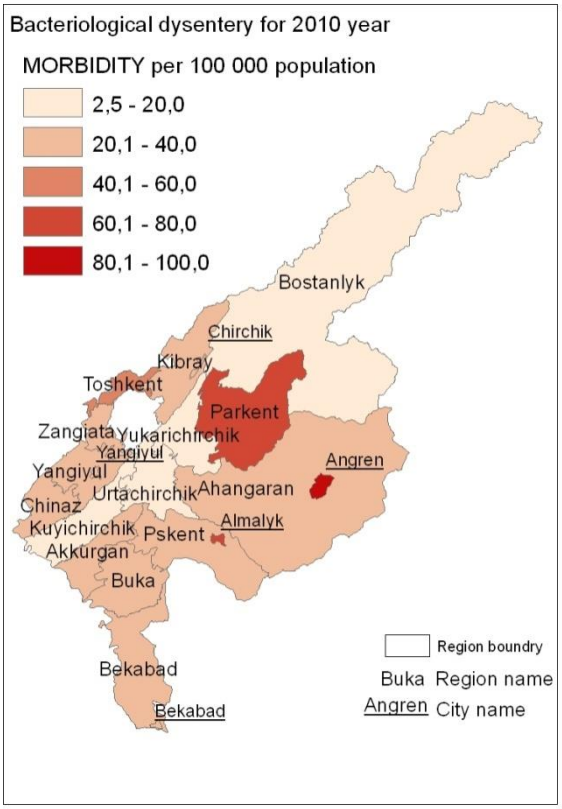


Figure 4.5: Distribution of bacterial dysentery in Tashkent province, 2010



Source: RISHOD

The temporal trends between 2006 and 2010 in the spatial distribution of morbidity rates of bacterial dysentery in Tashkent province are presented by the series of Figures 4.1 to 4.5. In all five years, the highest morbidity rates of bacterial dysentery are to be found in Parkent district and the towns of Angren and Olmalyk. Olmalyk town is heavily industrialised and home to the largest non-ferrous metallurgy plants in Uzbekistan, which mines and produces copper, lead, zinc, and others. The largest mining company active in Olmalyk town, Almalyk MMC, produces 6188 cubic meters of wastewater daily, of which about 17-19% overflows the wastewater reservoir that only has a volume of 2000 cubic meters. Reportedly, one quarter of the wastewater flow is discharged directly into water bodies, such as the river Gedzhikent, which is the main tributary of the Akhangaran river. The wastewater is characterised by high levels of COD (chemical oxygen demand), BOD (biological oxygen demand), and high concentrations of nonferrous metals, phenols, oil products, suspended solids, and dry residue. While the industrial wastewater and its low treatment rates and effectiveness does not explain the prevalence of bacterial dysentery, it points to the larger context of infrastructural weakness. There is insufficient contextual and socio-economic data about Parkent for hypotheses about causes of bacterial dysentery. Given that it is a hotspot, there is a need for a closer examination of the district.

2 CONCLUSIONS

The results of this geospatial analysis demonstrate the utility of GIS as a risk assessment approach. Using geospatial data from 2006 to 2010 for bacterial dysentery and acute intestinal infections, we were able to identify hotspots and their emergence. However, within the scope of this paper and the materials used, we were unable to go past hotspot identification, towards hypothesis generation about causative factors for the emergence of hotspots. The results of this geospatial analysis suggests the challenge with GIS-based population health risk assessments that do not sufficiently integrate the socio-economic context. The paper demonstrates the utility of GIS-based analysis as exploratory research, in its ability to identify case studies for hypothesis generation. While the apparent next logical step here would be to explore causative factors, it is important to go past a simple examination of the socio-economic characteristics of the hotspots that searches for correlations. Integrated risk assessment (WHO 2001) theorization offers some orientation: an important contribution is the recognition that human health risk assessment evolved independently of ecological risk assessment, and that there is a consequent need for integration to protect both humans and environment. The challenge for Uzbekistan is the adoption of such a holistic science-based approach.

3 References

Anselin, L. and Getis, A. (1991). Spatial statistical analysis and geographic information systems. Paper presented at the 31st European Congress of the Regional Science Association, Lisbon, Portugal.

Atherholt, T.B. et al. (1998). Effect of rainfall on Giardia and Crypto. *Journal of the American Water Works Association* 90(9): 66–80.

Atherton, F., Newman C.P., and Casemore D.P. (1995). An outbreak of waterborne cryptosporidiosis associated with a public water supply in the UK. *Epidemiology and Infection* 115(1): 123–131.

Bentham, G. and Langford, I.H. (2001) Environmental temperatures and the incidence of food poisoning in England and Wales. *International Journal of Biometeorology* 45(1): 22–26

Brown, P.J.B., and Economic and Social Research Council (1990). Poisson chi square mapping, GIS and geodemographic analysis: The spatial and aspatial analysis of relatively rare conditions. Working Paper 18. Great Britain: Urban Research and Policy Evaluation Regional Research Laboratory.

Checkley, W. (2000) Effects of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *Lancet* 355(9202):442-450.

Cliff, A.D. and Hagett, P. (1988). Atlas of the disease distributions: analytical approaches to epidemiological data. Oxford, UK; New York, USA: Basil Blackwell.

Cliff, A.D., P. Haggett & M. Smallman-Raynor (1998). Deciphering global epidemics: analytical approaches to the disease records of world cities, 1888-1912. Cambridge: Cambridge University Press.

Craun, GF. (1986) Waterborne diseases in the United States. Boca Raton: CRC Press, 1986.

Curriero, F.C., Patz, J.A., Rose, J.B., Lele, S. (2001) The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948–1994. *American Journal of Public Health* 91(8): 1194–1199.

Curry, MR (1998). *Digital Places: Living with Geographic Information Technologies*. London: Routledge

Epstein, P.R. (1999) Climate and health. *Science* 285(5426): 347–348.

Fayzieva, D. (2000) On some risk factors of water-borne infections. *Infection, Immunity and Pharmacology* No 1-2, pp. 10-13. (in Russian)

Fayzieva, D., Usmanov, I.A., Lutfullaev, R.A. (2001) Influence of anthropogenic pollution of the River Zarafshan on intestinal infections morbidity of the population. In C.A. Brebbia, *Water Pollution VI*, WIT Press, Southampton, Boston, pp. 227-235.

Fayzieva, D., Shirinova, N.G., Usmanov, I.A., Perziger, F.I. (2002) GIS-based assessment of epidemic situation in the Zaravshan River Basin. Proceedings of the 5th International Congress "ECWATECH-2002, Water: Ecology and Technology", Moscow, pp.483-484.

Fayzieva, D., Lutfullaev, R., Pertziger, F. (2002) Application of GIS for assessing the risk of water-borne diseases in the Samarkand Province. In D J Briggs et al, *GIS for Emergency Preparedness and Health Risk Reduction*, Chapter 16, Kluwer Academic Publishers, pp. 283-292.

Fayzieva D., Kamilova E., Nurtaev B. (2008) On development of GIS-based drinking water quality assessment tool for the Aral Sea area J.E. Moerlins et al. (eds.) Transboundary Water Resources: A Foundation for Regional Stability in Central Asia, Springer-Verlag, p.183-192.

Frost, F.J., Craun, G.F., Calderon, R.L. (1996) Waterborne disease surveillance. *Journal of the American Water Works Association* 88: 66-75.

Gatrell, A.C., Mitchell, J.D., Gibson, H.N., and Diggle P.J. (1991). Tests for spatial clustering in epidemiology: with special reference to motor neurone disease. In: C.F. Rose, ed. *New evidence in ALS.* London: Smith-Gordon.

Gatrell, A. & Senior, M. (2005). Health and health care applications. In P A Longley et al, *Geographical Information Systems: Principles, techniques, management and applications,* New York: Wiley, Chapter 66

Getis, A. and Ord, J.K. (1992) The analysis of spatial association by use of distance statistics. Geographical Analysis 24, pp189-206.

Gupta, R., Jay, D. and Jain, R. (2003) Geographic information systems for the study and control of infectious diseases. Map India Conference.

Herbst S. (2006) Water, sanitation, hygiene and diarrheal diseases in the Aral Sea area (Khorezm, Uzbekistan), PhD Thesis, 194.

Iskandarova Sh. T. (1999) Contemporary medical and hygienic approaches to solving of the Environmental Health Problems in the Republic of Uzbekistan. Doctoral dissertation, Tashkent, 1999.

Iskandarova, Sh.T. (1997) The role of water factor in spread of intestinal infections under the conditions of hot climate. Medical Journal of Uzbekistan, 2, pp.11-13, 1997.

Lisle, J.T., Rose, J.B. (1995) Cryptosporidium contamination of water in the USA and UK: a mini-review. *Aqua* 44(3): 103–117.

Lipp, E.K. and Rose, J.B. (1997) The role of seafood in foodborne diseases in the United States of America. *Revue Scientific et Technicale* 16(2): 620–640.

Ling-Ya Huang, Yu-Chun Wang, Chung-Ming Liu, Trong-Neng Wu, Chang-Hung Chou, Fung-Chang Sung and Chin-Ching Wu (2011), Water outage increases the risk of gastroenteritis and eyes and skin diseases. BMC Public Health 2011, 11:726.

Lawson, A.B. & F.L.R. Williams (2001) An introductory guide to disease mapping. Chichester, UK: John Wiley & Sons.

Madico, G. et al. (1997) Epidemiology and treatment of cyclospora cayetenanis infection in Peruvian children. *Clinical Infectious Diseases* 24: 977–981.

Parmenter, R.R., Yadav E.P., Paramenter C.A., Gage, K. (1999) Incidence of plague associated with increased winter-spring precipitation in New Mexico. *The American Journal of Tropical Medicine and Hygiene*. 61(5): 814–821.

Rose, J.B.S. (2000) Climate and waterborne outbreaks in the US: a preliminary descriptive analysis. *Journal of the American Water Works Association* 92: 77–86.

Rose, J.B., Epstein P.R., Sherman B.H., Bernard S.M., Patz J.A. (2001) Climate variability and change in the United States: potential impacts on water- and foodborne diseases caused by microbiologic agents. *Environmental Health Perspectives* 109 (Supplement 2): 211–221.

Semenza, J.C., Roberts, L., Henderson, A., Bogan, J., Rubin, C.H. (1998) Water distribution system and diarrheal disease transmission: a case study in Uzbekistan. American Journal of Tropical Medicine and Hygiene, 59(6), pp. 941-946.

Schwartz, J., Levin, R. (1999) Drinking water turbidity and health. *Epidemiology* 10: 86–90.

Salazar-Lindo, E. (1997) El Niño and diarrhoea and dehydration in Lima, Peru. *The Lancet* 350(9091): 1597–1598.

van der Veen, A.A. (1992). GIS awareness in epidemiology and environmental studies. In: *Proceedings of the EGIS'92 Conference*. Utrecht, EGIS Foundation.

Verdonschot, P. F. (2000) Hydrobiologia, 422, p 389.

WHO World Health Organisation (2006). Burden of disease statistics. www.who.int/whosis/en ,WHO, Geneva.

WHO (2001) Framework for the integration of health and ecological risk assessment. Integrated Risk Assessment: Report prepared for the WHO/UNEP/ILO International Programme on Chemical Safety. Available: http://www.who.int/ipcs/publications/new_issues/ira/en/ (last accessed November 2016)