Geospatial Analysis of Typhoid and Malaria Prevalence and their risk factors in Rawalpindi City, Pakistan

Aziz, N. and Ahmad, S. S.
Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi, Pakistan
E-mail: drsaeed@fjwu.edu.pk

Abstract

In developing countries like Pakistan, typhoid and malaria are widespread due to environment of hygiene and sanitation. This study explores GIS-aided spatial analysis of distribution of malaria and typhoid in urban unplanned settlements of Rawalpindi along Nullah Lai. The selected population consists of 500 households and 5 public hospitals. Questionnaires were given to all the participants in the study area. The data was then examined by statistical analysis and also by integrating it in GIS. The prevalence of typhoid infection was high in people who drank municipal water than those who use ground water or filter plant water. Prevalence of malaria and typhoid was also higher in households which exhibit lower socioeconomic status, low clean water index (CWI), and overcrowded houses. With the aid of these analyses it will be effective to monitor and identify high rate disease locations and to implement precautionary measures.

1. Introduction

Worldwide waterborne diseases are amongst the most recent emerging and re-emerging diseases. Waterborne diseases are established as the biggest health threat in developing countries as they contribute 70-80% health problems (Obi et al., 2010). Globally most prevalent tropical waterborne diseases are malaria and enteric fever (Khan et al., 2005 and De Vries et al., 2007). Both diseases have been greatly associated with poverty and under development with significant mortality and morbidity (Uneke, 2008). Approximately 300-500 million cases of malaria are reported each year globally leading to 1-2 million deaths (Khan et al., 2005 and Riegelhaupt et al., 2010), with more than 26% cases occurring in Asia (RBM, 2010) and 500,000 cases in Pakistan. It is estimated that 16-33 million cases of typhoid reported each year globally, 80% of which occurred in South Asia (Farooqui et al., 2009), and 216,000 – 600,000 deaths per year of which 90% occurred in Asia (Bhutta et al., 2011). Due to poor economic conditions and rising shortage of affordable housing, most of the spatial growth in numerous world's fastest growing cities leads to the expansion of informal settlements where inhabitants are not provided with basic infrastructure like sewage system, waste collection system, safe drinking water etc. (Patel and Burke, 2009 and Penrose et al., 2010). Human health and well-being of population is greatly threatened by unplanned urban expansion. Mostly development

does not benefit the poor inhabitants in a positive way. Instead, they are more vulnerable to diseases like malaria, typhoid, etc. (United Nations Human Settlements Program, 2003). Globally 2.6 billion (70% lives in Asia) and 884 million (51% lives in Asia) people are not provided with improved sanitation facilities and safe potable water respectively. In Pakistan 75 - 90% people are provided with safe drinking water and less than 50% are provided with improved sanitary services. Worldwide 1.1 billion people practice open defecation, of which 48 million lives in Pakistan (Ince et al., 2010 and WHO and UNICEF, 2010). Malaria and typhoid are a great burden to the health system; however, the extent of problem had not been determined. Generally in developing countries disease cases are not informed to a centralized surveillance system because most of the waterborne diseases remain unidentified or misdiagnosed (Mitchell, 2009). Due to the innate ability of Geographic Information System (GIS) to maintain both spatial and non-spatial data provides an excellent framework for management of diseases and a number of studies has been conducted in this regard (Osei and Duker, 2008, Srivastava et al., 2009 and Abdullahi et al., 2010). This study explores GIS-aided spatial analysis of the distribution of malaria and typhoid in an urban unplanned settlement of Rawalpindi and identifies

their risk factors to implement precautionary measures by health agencies for public health.

2. Study Area

The study area is 1.5 km along Nullah Lai from Murir Chowk to New Katarian in Rawalpindi. Rawalpindi lies between 33° - 28′ and 33° - 48′ north latitudes and 72° - 48′ and 73° - 22′ east longitudes (Figure 1). The total area of Rawalpindi city is 250 square kilometer. The total population of Rawalpindi is 2.2 million and is the fourth largest city in Pakistan (Adeel, 2010). The rate of literacy among males and females is 87% and 68% respectively. Populace density is 637 persons per square kilometer. The average number of persons living in a single room is 2.68 in Rawalpindi district. In Rawalpindi according to 2004-05 data, 33% population is living below the poverty level. Average per capita income in Rawalpindi district is 1729 Rupees per month (18.42 US$ per month) (ADB, 2005). Climatic condition of Rawalpindi is sub humid to tropical. Average maximum temperature of Rawalpindi ranges from 25.6°C to 39.4°C in June and average minimum temperature ranges from 3.2°C to 16.7°C in January. Annual average rainfall in city is 1,044 mm, of which 50% is occurring in monsoon (July to September) (ADB, 2005). Nullah Lai moves from north to south through the developed areas of the city and finally ends up in Soan River. In south of Margalla Hills, total Lai Nullah Basin (Tributary River / Stream) drainage area is 244 km², with 55% of the watersheds falling within Islamabad territory and the remaining within the downstream Rawalpindi Municipal and Cantonment limits. There are five major tributaries of Nullah Lai including: Saidpur Kas, Kanitanwali Kas, Tenawali Kas, Bendran wali Kas and Niki Lai. In addition there are 20 other minor tributaries of Nullah Lai. Nullah Lai maximum length from its beginning point to its final joining with Soan River is approximately 45 km (Khan and Mustafa, 2007). Nullah Lai Basin carries away rain runoff and almost all of the sewage from Islamabad and also the local waste is dumped in it. Household solid waste is also discarded in Nullah Lai (ADB, 2005).
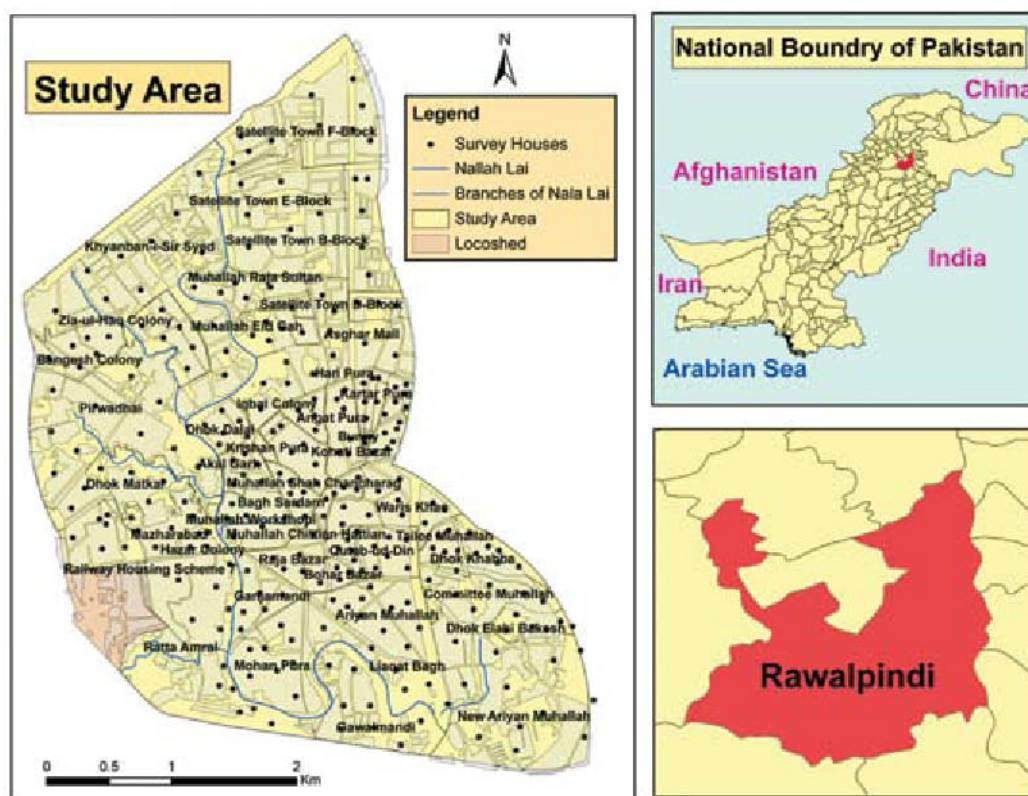

Figure 1: Map of study area

3. Materials and Methods

3.1 Spatial Database

Thematic map or base maps were prepared from Islamabad- Rawalpindi guide map obtained from Survey of Pakistan on 1:30,000 scale using Arc GIS to obtain a base line data. The guide map was firstly scanned up to the resolution that made all the important features clear and vivid. It was then geo-referenced by assigning the WGS-1984 coordinate system. Main features like (1.5 km buffer along Nullah Lai, Area Division, roads, railway line, Nullah Lai, Branches of Nullah Lai, Schools, Hospitals and Built up Area) were digitized using editor tool bar and then labeled properly to generate the digital output.

3.2 Attributed Data Bases

Attributed data was collected by questionnaire survey from residential area. Questionnaires were filled by all the participants in the study. Subjects were questioned regarding the presence and the regularity of symptoms referable to malaria and typhoid. Another set of questions were related to socio-economic backgrounds of the individuals (subjects' education, occupation, and family income). Household hygiene questions were related to the source of water used for drinking, cooking and bathing purposes (municipal water, boring water or filtered water), taste and odor of water, impurities in water, storage facility of water in house, frequency of cleaning the water storage tanks, and excreta disposal facilities (indoor or outdoor). Questions related to the sanitation practices included the details about the frequency of bathing, hand washing per day, boiling of water before drinking and reuse of water. Survey questionnaire also included the questions related to the living conditions of the subjects (number of rooms, number of persons residing in the house). Other questions included the waste collection system in the area, sewage system conditions in the area, polluted water runoff, medical facilities in the area and distance from Nullah Lai. Total of 500 survey questionnaire were filled in. In all, 450 respondents were selected from Household questionnaire survey to identify popular water sources, common waterborne diseases and other related information. Previous literature was used to prepare the crowding index and clean water index (CWI) (Nurgalieva et al., 2002 and Ahmad et al., 2007).

Crowding index was used to assess the level of density in the homes. Crowding index defined as total number of family members divided by total number of rooms in the home. The crowding index was scored as low (scores 0-1), middle (scores 2-3), or high (scores >3) (Nurgalieva et al., 2002 and Ahmad et al., 2007). Categorization for clean water index was based on the combination of 3 factors: regularity of boiling water before drinking, frequency of restoring and reusing water, and frequency of bathing and showering. Three levels were identified, ranging from high to low. Socioeconomic status was categorized based on the educational and occupation level of the subject using a modification of the Hollingshead index (Hollingshead, 1957). Socioeconomic conditions were identified using four educational levels and five occupational categories. Four socioeconomic statuses were identified in our population: lower upper class, upper middle class, lower middle class and lower class. The data was analyzed using the SPSS 17. And in the final step maps showing the surveyed houses were over laid on the base map to generate the spatial distribution map of malaria and typhoid prevalence, clean water index, crowding index and socioeconomic status of study area.

3.3 Spatial analysis by Choropleth maps

GIS is very powerful tool for analyzing waterborne diseases distribution, identifying risk area and in early warning and prediction. The simplest tool in ArcGIS for spatially analyzing diseases is symbology, in this study it was used to create Choropleth maps of malaria, typhoid, Clean Water Index, Crowding Index and water source. Choropleth mapping is a type of thematic map in which areas are colored or shaded to reflect the value of mapped phenomena or display classes of value. In order to construct a choropleth map, data is aggregated or generalized into classes or categories that are represented on the map by grades of color or shading.

3.4 Statistical analysis

Bi-variant correlation was applied to identify the risk factors for the incidence of malaria and typhoid in the study area. The dependent variables for the analysis were malaria and typhoid, and the independent variables were indicators (i.e. CWI and crowding index) collected through household surveys.
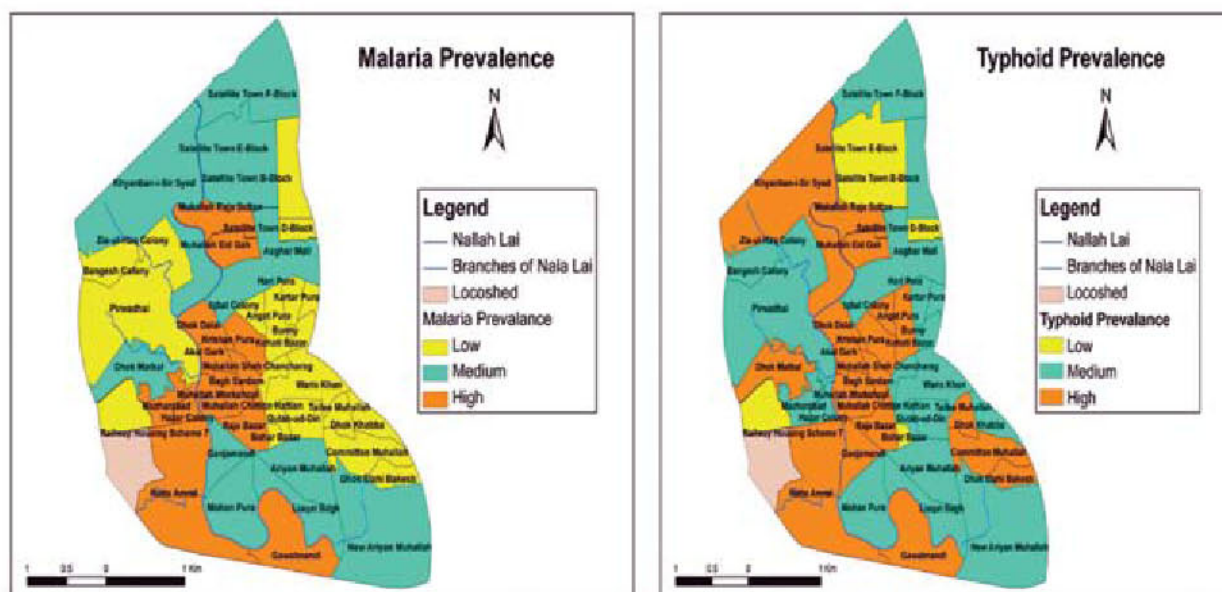
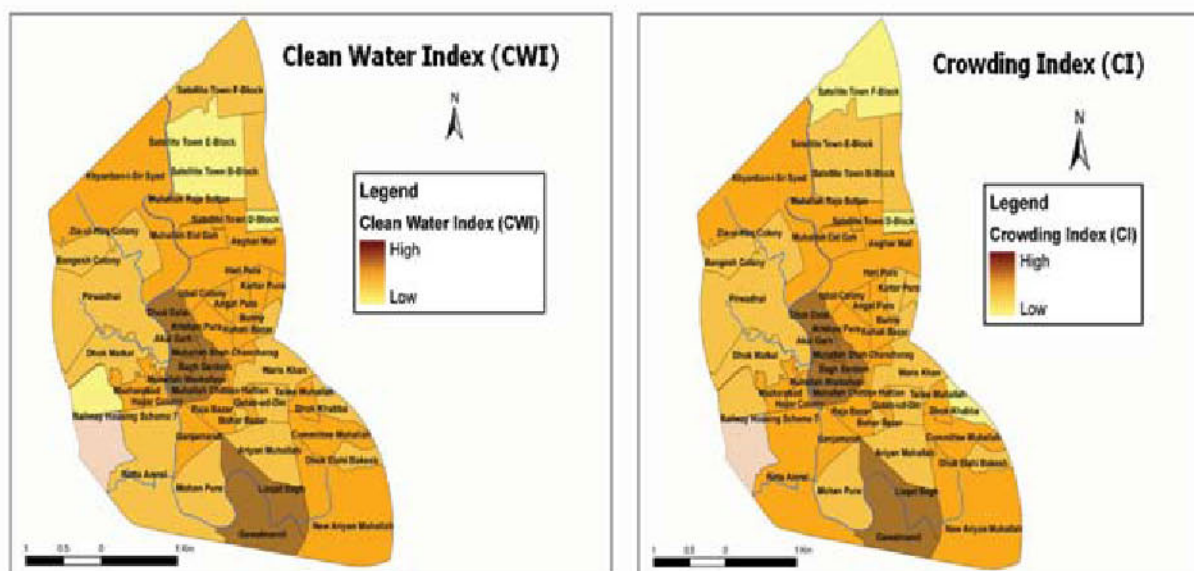Figure 2: Malaria and typhoid prevalence in study area according to residential survey

Figure 3: Clean Water Index (CWI) and Crowding Index of the study area

4. Result and Discussion

4.1 Household Survey

Worldwide most prevalent tropical diseases are malaria and enteric fever (Khan et al., 2005 and De Vries et al., 2007). Both diseases have been greatly associated with poverty and under development with significant mortality and morbidity (Uneke, 2008). A total of 450 household questionnaires were included in results. No. of questionnaires filled in from the each muhalla (Arabic word for neighborhood) depend upon size of an area. High malaria and typhoid prevalence was observed in the areas which are close to the Nullah Lai (Figure 2). Especially the central and southern old muhallahs in study area which were not properly planned, houses were very small and lanes were too congested surrounded by stagnant water and heaps of garbage and there were no basic facilities like safe drinking water, improved sewage system, proper waste

collection system and mostly poor people lived in these areas. Most of these muhallas were established by Hindus and Sikhs before partition. Crowding index was also found to be the highest in these old muhallas in the center of the study area. Clean water index (CWI) also vary in the study area. Areas of upper middle class had access to good quality of water as compared to unplanned settlements of the city including the lower middle class and complete lower class which have poor quality of water as well as high crowding index as shown in figure 3.

Crowding index is very important household hygiene condition indicator. The results obtained indicated that the infection rate of typhoid and malaria was found higher in the areas with high crowding index as compared to the areas with low crowding index. One of the major reasons of waterborne diseases is the low socioeconomic conditions. According to the results, most of the study area comes under the lower middle class and lower class.
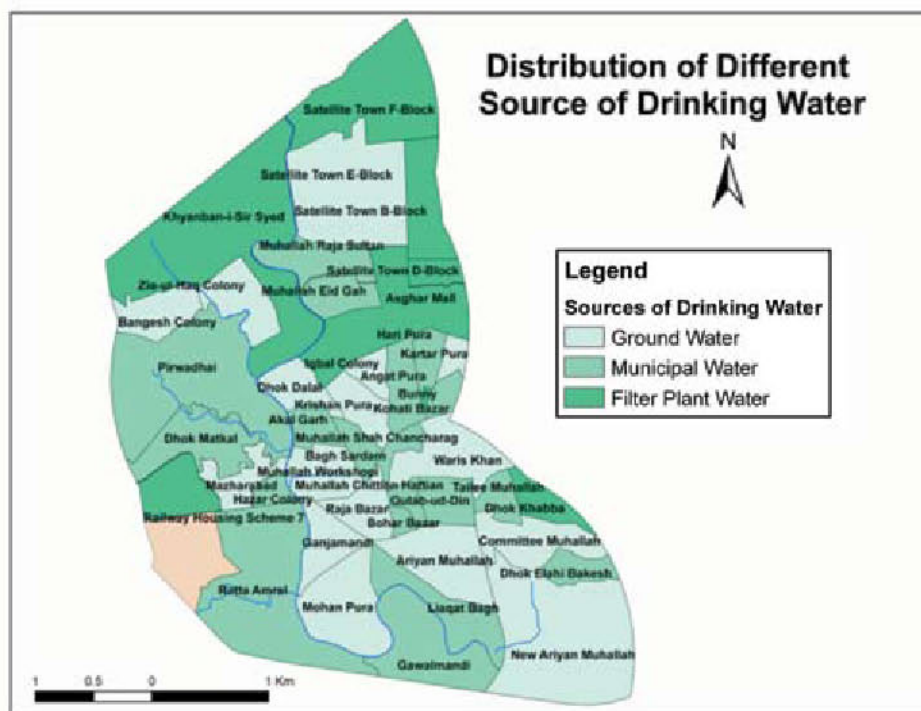

Figure 4: Distribution of different source of drinking water in study area
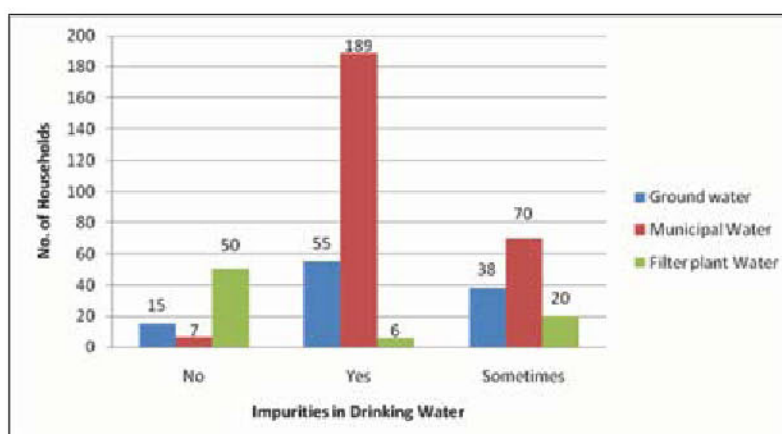

Figure 5 Crosstab Analysis of source of drinking water and impurities in drinking water

Table 1: Frequency analysis of source of drinking water in study area

Source of drinking water	% Houses
Ground Water	24
Municipal Water	59
Filter plant Water	17

Table 2: Correlation Matrix of typhoid and malaria prevalence and their risk variables

Variables	Coefficients				
	Malaria	Typhoid	CI	CWI	DNL
Malaria	1 0.000				
Typhoid	0.152 0.124	1 0.000			
CI	0.541** 0.000	0.667** 0.000	1 0.000		
CWI	-0.002 0.986	0.644** 0.000	0.659** 0.000	1 0.000	
Distance from Nullah Lai (DNL)	-0.624** 0.000	-0.235* 0.016	0.210* 0.032	0.198* 0.044	1 0.000

This indicated that most of the study area is socio-economically poor, which was another very strong reason for malaria and typhoid, as due to poverty inhabitants were not aware of proper hygiene rules and had no basic facilities. Studies conducted in other areas also showed similar associations. Toprak and Erdogan (2008) results also showed higher typhoid prevalence in south east region of Turkey because these cities were known for low socioeconomic conditions. Najera (1994) argued that reduction in malaria cases from parts of Europe was correlated with economic development associated to agricultural growth rather than vector control or chemoprophylaxis. Nigerian community based survey results indicated the more malaria burden on poor as compared to rich (Worrall et al., 2002). Studies analyzing socioeconomic status using assets, occupation and education all result indicated that severity of malaria's effects were inversely associated with socioeconomic status (Rajasekhar and Nandakumar, 2000 and Okrah et al., 2002). In the present study, significant association was found between typhoid and use of water, e.g CWI, as also reported by previous studies. Accurate household hygiene conditions were represented by CWI. Results of CWI showed that those household who exhibited the high CWI have low prevalence of typhoid, while those with low CWI have high prevalence of typhoid. Two popular sources of

water in study area were municipal water and ground water as shown in table 1. Crosstab analysis (figure 5) indicated that most of the municipal water and ground water users had impurities their drinking water. Majority of the study area residents of study are complained that underground pipelines system for municipal water and sewage were broken leading to the mixing of water from two pipes. The contamination of the two popular sources of domestic water (municipal water and ground water) indicated that most of the inhabitants of study area were at high risk of getting typhoid. An outbreak of typhoid was reported in Maharashtra, Bangalore, West Bengal and Pondicherry in India. Results analysis indicated that disease was strongly associated with use of drinking water from government tanks. As the water of government tanks were contaminated with feces (Anand and Ramakrishnan, 2010). An outbreak of typhoid fever in Taiwan in 1983 was associated with contamination of common drinking water source, also confirmed by laboratory result (King et al., 1989). Significant association was also found between malaria and typhoid prevalence with Nullah Lai. Most of the liquid waste and solid waste of twin cities were dumped in Nullah Lai as there is no proper waste collection system available in the area. As a result, Nullah lai has become the most suitable site for mosquitoes breeding. In summer,

their attack rate increased greatly. Another major cause of malaria in study area was the combined sewage system, where rainfall runoff and sewage waste water were carried away in the same pipelines. Pipelines overflowed during heavy rainfall and sewage and domestic waste were ultimately sent to Nullah Lai. Domestic waste was often dumped into sewage pipelines resulting in their blockage and also they become suitable sites for mosquitoes breeding, a leading cause of malaria. A study conducted in New Dehli, India indicated the difference in malaria occurrence in different income houses. Analysis suggested that these differences are associated to environmental conditions existing outside and inside their homes, such as poor sewage disposal, drainage system, open blocked drains, indoor water shortage etc. (Singh and Rahman, 2001). According to questionnaire based study, major obstacle in typhoid fever control in Singida urban area were lack of knowledge about personal hygiene, access to clean drinking water, inappropriate drainage system and problems of unhygienic toilets (Malisa and Nyaki, 2010). Bivariable correlation analysis of malaria and typhoid prevalence in relation to independent variables at household level, including Crowding index (CI), Clean Water Index (CWI) and distance from Nullah Lai (DNL) were shown in table 2. Analysis of attributable risk factors indicated that malaria was positively associated with crowding index (Coefficient = 0.541, P = 0.000) and negatively related with and distance from Nullah Lai (Coefficient = -0.624, P = 0.000). No significant relationship was found between malaria and Clean Water Index (CWI) and typhoid. Typhoid was positively associated with crowding index (Coefficient = 0.667, P = 0.000), while negatively related with clean water index (Coefficient = -0.644, P = 0.000) and distance from Nullah Lai (Coefficient = -0.210, P = 0.032). Prevalence of typhoid can be reduced by increasing awareness regarding personal hygiene such as hand washing after using the toilet and before handling food and cost effective water purification mechanisms including chlorination and boiling. Malaria incidence can be reduced by improving the socioeconomic condition of the area, reducing human-vector contact, insecticide-treated bed nets, indoor insecticide spraying, reducing stagnant water ponds and cleaning the surrounding environment. GIS-aided analysis and statistical analysis further facilitates the epidemiologist to take the appropriate steps to reduce the incident rate of diseases.

4. Conclusion

In order to control typhoid and malaria, it is very important to provide the entire basic infrastructure to the inhabitants to improve their livelihood. GIS and statistical analysis facilitate the understanding of disease epidemiology and helps to identify the risk zone to formulate and implement precautionary measurements for government and policy makers. In this study, spatial and statistical analyses were applied on the distribution of typhoid and malaria infections. Study indicated that malaria and typhoid prevalence was greatly associated with poor socio-economic and environmental conditions. Typhoid and malaria prevalence was high in old unplanned urban settlements with high crowding index, low clean water index and where safe drinking water sources were not available. Therefore to address the challenges a rapid response from governmental organization is required.

References

Abdullahi, F. B., Lawal, M. M. and Agushaka, J. O., 2010, Design and Implementation of a Web-Based GIS for Public Healthcare Decision Support System in Zaria Metropolis. *IJRRAS*, 4 (4), 435-439.

Adeel, M., 2010, Assessing the Implementation of Rawalpindi's Guided Development Plan through GIS and Remote Sensing. *REAL CORP 2010: Cities for Everyone. Liveable, Healthy, Prosperous*, Vienna, Austria, 18 - 20 May.

Anand, P. K. and Ramakrishnan, R., 2010, Investigation of the Outbreak of Typhoid in a Village of Thar Desert Rajasthan, India. *India Journal of Medical Research*, 131, 799–803.

Asian Development Bank (ADB), 2005, Summary environmental impact assessment Rawalpindi environmental improvement project in the Islamic Republic of Pakistan. 1-46.

Bhutta, Z. A., Khan, M. I., Soofi, S. B. and Ochiai, R. L., 2011, Hot Topics in Infection and Immunity in Children VII. *Advances in Experimental Medicine and Biology*, 697, 17-39.

De Vries, J. J. C., Assen, S. V., Mulder, A. B., and Kampinga, G. A., 2007, Positive Blood Culture with Plasmodium Falciparum: Case Report. *American Journal of Tropical Medicine and Hygiene,* 76(6), 1098-1099

Farooqui, A., Khan, A. and Kazmi, S. U., 2009, Investigation of a Community Outbreak of Typhoid Fever Associated with Drinking Water. *BMC Public Health,* 9, 476-482.

Hollingshead, A. B., 1957, *Two factor Index of Social Position,* (New Haven: Yale University Press).

Ince, M., Bashir, D., Oni, O. O. O., Awe, E. O., Ogbechie, V., Korve, K., Adeyinka, M. A., Olufolabo, A. A., Ofordu, F., and Kehinde, M., 2010, Rapid Assessment of Drinking Water Quality in the Federal Republic of Nigeria: Country Report of the Pilot Project Implementation in 2004-2005. WHO and UNICEF, 1-42.

Khan, F., and Mustafa, D., 2007, Navigating the # of the Pakistani Hazardscapes: Disaster Experience Versus Policy. *Working with the Winds of Change: Towards Strategies for Responding to the Risks Associated with Climate Change and other hazards. ProVention Consortium, Institute for Social and Environmental Transition-International and Institute for Social and Environmental Transition-Nepal. Kathmandu, Nepal,* edited by M. Moench and A. Dixit (Kathmandu: Prevention Consortium).

Khan, M. A., Meken, S. F. and Smego, R. A., 2005, Concurrent Malaria and Enteric Fever in Pakistan. *Singapore Medical Journal,* 46(11), 635-638.

King, C. C., Chen, C. J., You, S., Chuang, Y. C., Huang, H. H. and Tsai, W. H., 1989, Community-Wide Epidemiological Investigation of a Typhoid Outbreak in a Rural Township in Taiwan, Republic of China. *International Journal of Epidemiology,* 18(1), 254-260.

Malisa, A. and Nyaki, H., 2010, Prevalence and Constraints of Typhoid Fever and Its Control in an Endemic Area of Singida Region in Tanzania: Lessons for Effective Control of The Disease. *Journal of Public Health and Epidemiology,* 2(5), 93-99.

Mitchell, R., 2009, *Environmental Microbiology,* 2nd edition, (New Jersey: John Wiley and Sons).

Najera, J. A., 1994, The Control of Tropical Diseases and Socioeconomic Development (with Special Reference to Malaria And Its Control). *Parassitologia,* 36, 17-33.

Nurgalieva, Z. Z., Malaty, H. M., Graham, D. Y., Almuchambetova, R., Machmudova, A., Kapsultanova, D., Osato, M. S., Hollinger, F. B. and Zhangabylov, A., 2002, Helicobacter Pylori Infection in Kazakhstan: Effect of Water Source and Household Hygiene. *American Journal of Tropical Medicine and Hygiene,* 67, 201-206.

Obi, R. K., Orji, N. M., Nwanebu, F. C., Okangba, C. C., and Ndubuisi, U. U., 2010, Emerging and Re-Emerging Infectious Diseases: the Perpetual Menace. *Asian Journal of Experimental Biological Sciences,* 2(1), 271-282.

Okrah, J., Traore, C., Pale, A., Sommerfeld, J. and Muller, O., 2002, Community Factors Associated with Malaria Prevention by Mosquito Nets: An Exploratory Study in Rural Burkina Faso. *Tropical Medicine and International Health,* 7, 240-248.

Osei, F. B., and Duker, A. A., 2008, Spatial Dependency of *V. cholera* Prevalence on Open Space Refuse Dumps in Kumasi, Ghana: A Spatial Statistical Modeling. *International Journal of Health Geographics,* 7, 62-78.

Patel, R. B. and Burke, T. F., 2009, Urbanization - An Emerging Humanitarian Disaster. *New England Journal of Medicine,* 361, 741--743.

Penrose, K., Castrom, M. C. D., Werema, J. and Ryan, E. T., 2010, Informal Urban Settlements and Cholera Risk in Dar es Salaam, Tanzania. *PLoS Neglected Tropical Diseases,* 4(3) e631, 1-11.

Rajasekhar, M. and Nandakumar, N. V., 2000, Occupational Malaria and Health Risk Among Select Occupational Health Care Employee Groups in an Urban Hospital at Tirupati, A. P. *Indian Journal of Malariology,* 37, 53-60.

Riegelhaupt, P. M., Frame, I. J., and Akabas, M. H., 2010, Transmembrane Segment 11 Appears to Line the Purine Permeation Pathway of the Plasmodium Falciparum Equilibrative Nucleoside Transporter 1 (Pfent1). *Journal of Biological Chemistry,* 285(22), 17001-17010.

Singh, A. L. and Rahman, A., 2001, Malaria and Related Environmental Issues in India: A Case Study of Aligarh City. *Geojournal,* 89, 89-99.

Srivastava, A., Nagpal, B. N., Joshi, P. L., Paliwal, J. C. and Dash, A. P., 2009, Identification of Malaria Hot Spots for Focused Intervention in Tribal State of India: a GIS Based Approach. *International Journal of Health Geographics,* 8(30), 30-38.

Toprak, D. and Erdogan, S., 2008, Spatial Analysis of the Distribution of Typhoid Fever in Turkey. The *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XXXVII (B8), 1367-1371.

Uneke, C. J., 2008, Concurrent Malaria and Typhoid Fever in the Tropics: The Diagnostic Challenges and Public Health Implications. *Journal of Vector Borne Diseases*, 45, 133-142.

United Nations Human Settlements Program, 2003, The Challenge of Slums: Global Report on Human Settlements 2003. (Nairobi: UN-HABITAT).

Worrall, E., Basu, S. and Hanson, K., 2002, The Relationship between Socio-Economic Status and Malaria: a Review of the Literature. Presented in *Ensuring that Malaria Control Interventions Reach the Poor*, London, 5th-6th September.