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Spatial Patterns and Trends of *Escherichia coli* in Public Water Supply System of Lahore, Pakistan

Isma Younes[a], Abdul Ghaffar[a], Rakhshanda Sadaf[b]*, Naheeda Naseem[a] and Muhammad Shafiq[c]

[a]Department of Geography, University of the Punjab, Lahore, Pakistan

[b]Department of Geology, Federal Urdu University of Arts, Science and Technology, Karachi, Pakistan

[c]Directorate of Earth Sciences, SUPARCO, Karachi, Pakistan

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Abstract. Most of the Northern and Central part of Lahore district is supplied with ground water by Water and Sanitation Government Authority. The quality of public water supply is getting deteriorating due to increasing population of Lahore city. Moreover, the effects of microbial water pollutants on health of population of study area have been addressed. In this research, presence of *Escherichia coli* in pre & post monsoon seasons has been focused. The water samples were taken from tube wells as well as adjacent houses. A questionnaire survey was also conducted to find out the responses of people in study area. It was clear from the results of the study that *E. coli* were detected in all the water samples of public water supply system. An increase in growth of pathogens was also noticed in post monsoon season. It was also proved from study that many people were suffering from diarrhoea at sample places where *E. coli* were identified. The mixing of sewage with drinking water was the major cause of presence of pathogens in water samples of houses although they were less or absent in water samples of tube wells.

Keywords: spatial patterns, *Escherichia coli*, water supply system, sewage contamination

Introduction

An adequate supply of safe drinking water is a major prerequisite for the health. Gray (2010) analyzed that water borne diseases are a major cause of deaths around the world. According to WHO, 1.8 million people die due to diarrhoea and cholera throughout the world (Hamid *et al*., 2013, Poff and Aregai, 2002) and nine out of ten deaths are among children and nearly all of these deaths occur in the developing countries (Nicholas, 2004). Drinking water needs to be free from all the pathogens, all solids, animal and human waste (Goel, 2011). It is assigned to be polluted when anthropogenic pollutants spoil it and it does not remain any more useful for human beings as potable water (EPA, 2015). There are many natural sources that lead to change in ecological status of water and quality such as algal bloom, earthquakes, volcanoes, floods and storms (Paul, 2011; Ghosh, 2008).

Drinking water is borrowed from two major sources which are surface water and groundwater. All water contains natural impurities, particularly inorganic impurities that emanate from geological bed through which the ground water flows and, to some extent, man-made pollution caused by both chemicals and microorganisms. In general, surface waters are more vulnerable to pollution than groundwater. There are many sources of anthropogenic contaminants, some of which are more critical than others. These are point and non-point sources. Discharges from industrial areas and sewage treatment works are point sources and these sources are more immediately detectable and controlled such as urban and agricultural runoff (Prica, 2010). Such sources can give rise to a significant variation in the contaminant load over time.

Quality of ground water depends on many natural factors such as nature of rocks, nature of rainfall and nature of already existing ground water (Ahmad *et al*., 2011). It is also affected by a number of anthropogenic factors such as explicit release of industrial waste in water bodies, urban sewage and agricultural runoff (Agarwal, 2009). Pollutants in groundwater are very less as compared to surface water. As soil acts as a filter for many pollutants. Water pollutants also infiltrate in ground water from septic and underground tanks that are used for management of sewage treatment (Goel, 2011).

World Health Organization asserted that water quality is not up to the mark in many parts of Lahore, Pakistan. First of all, Water and sanitation Authority (WASA) was not following the drinking water quality standards set by WHO (WHO, 2011; 2000; 1997) at many locations (WASA Tubewells). Secondly, although the water quality

*Author for correspondence; E-mail: r.sadaf@fuuast.edu.pk

is better in water samples of tubewells but its quality becomes poor as it travels to end points (houses) of the water supplying system. The deteriorated conditions of old water supply pipe lines and sewage collecting pipe lines allow sporadic mixing of water from both pipe lines. As a result of mixing of sewage in drinking water, many water-borne diseases are common among people of the study area.

This study has focused on Lahore district. WASA is the only public water supplying authority of Lahore district but it does not supply water to the whole district rather it supplies water to only a small part of the North and Centre of the district. This research was conducted to identify the patterns of *Escherichia coli* in public water supply system and to study its effects on human population. The pathogen selected for this study was *Escherichia coli* as it is one of the major causes of diarrhoea among people.

Materials and Methods

A primary data collection was done for measuring microbial quality of water samples as well as for obtaining information about responses of population. The water samples were collected from sources (tubewells installed by WASA) of public water supply system. One hundred and twenty-two tubewells were taken as sample sites for taking water samples to analyze microbial parameters. The same number of water samples was also taken from houses. As the district is having nine towns and one cantonment area, water samples were collected from all the towns of the Lahore district. Water samples for analysis were also collected from nearby houses. The use of public water supply by target population was confirmed. Water samples were collected and analyzed both in pre and post monsoon seasons to study the changing pattern of growth of microbes in different temperatures and other climatic conditions. WHO Standards were used to measure, analyze and detect different bacteria in water samples. Data about water sources, quality of public water supply, socio-economic conditions of people and disease prevalence among people was collected using questionnaires. The data about number of patients of diarrhoea were collected through questionnaire survey.

Inverse Distance Weighting (IDW) method of interpolation was applied for mapping of *E. coli*. Wong applied the Standard Deviation (Wong and Lee, 2005) using tool of directional distribution for measuring the geographic distribution. This technique focuses on the trend of spatial distribution of *E.coli* in public water supply system in study area. It also reflects that the water of sample locations was polluted in both seasons. Scott also calculated the center of data using spatial distribution technique (Scott and Janikas, 2010).

Figure 1 shows the sample locations of water samples for analyzing microbial parameter in the study area. Blue dots highlight the tubewells and red dots focus the sample houses. A boundary was marked around these sample locations so that patterns of microbial pollution can be shown accurately.

Results and Discussion

The colour hues are applied in Fig. 2-3 to display patterns of *E.coli*. Dark brown hue was calling attention to the sample locations where *E.coli* was not detected. Yellow to green hues were used for showing the locations where it was detected but number of colonies was less. Besides this the light blue to dark blue colour shows the sites where quality of drinking water was worst due to presence of large number of colonies of *E.coli*.

Figure 2 highlights the patterns of *E.coli* in pre-monsoon water samples of tubewells. Table 1 shows that *E.coli* was detected in both seasons in water samples at many places. Figure 1 shows that *E.coli* was detected in water samples of Baghechi, Belal Park, Lahori Gate, Sheranwala Gate, Yaki Gate, Paniwala Talab, Akbari Gate, Masti Gate, Texali Gate, Taj Pura, Paki Thatti, Akbar Shaheed road, Kot Khwaja Saeed, Begumpura,

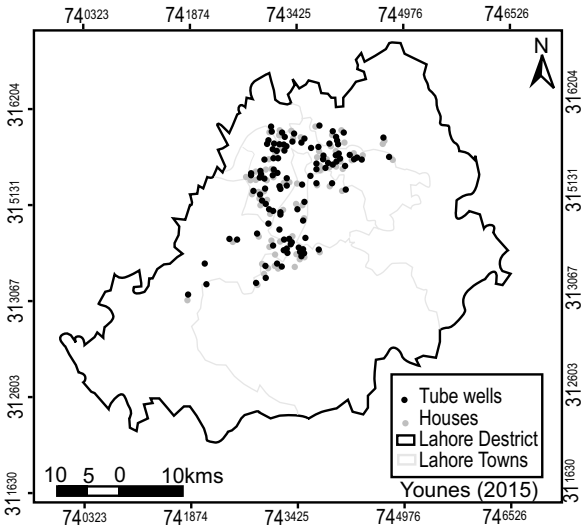

Fig. 1. Sample locations in study area.

Table 1. *E.coli* in water samples at different sample locations

Locations	Houses-Pre	Houses-Post	TW-Pre	TW-Post
Loction93	0	1	0	0
16B-1 block phatniwala	2	17	1	4
2C-II township	4	15	0	2
3D-II township	10	15	1	7
3D-1 township	7	15	0	5
6A II township	32	36	1	13
Ahmed block	4	6	2	5
Akbari gate	16	31	3	5
Al fasial town burji	0	1	0	1
Amer sidu phatak	18	36	0	0
Askari	0	0	0	0
Baba farid colony	0	0	0	0
Badami bagh	30	41	0	0
Bagh gul begum	1	1	0	1
Bagh munshi ladha	9	11	1	2
Baghich	27	45	3	4
Baghrian	2	7	0	0
Bata pur	0	1	0	0
Begumpura	6	17	2	1
Bhatti colony	0	1	0	1
Bilal park	2	5	2	5
Cblock faisal town	11	17	6	14
Chah miran	2	13	1	1
Chandni chowk town ship	2	5	1	4
CMH	0	0	0	0
D block greentown	12	30	2	2
Daroghawala	6	8	3	7
Dars bary mian	17	24	8	12
Data nagar	11	21	0	7
Dhobi ghat	11	15	0	0
Dhobi mandi	3	7	1	1
Dry port	11	17	0	0
F and v market	0	0	0	0
Fate h garh	1	1	0	0
G-4johar town 1	4	12	0	1
Garison golf	0	0	0	1
General hospital	0	1	0	1
Ghaziabad	10	15	0	1
Girls hostel pu 7	0	0	1	1
Green town	24	37	0	0
Gulshan colony mustafabad	1	1	1	0
Gulshan block	7	9	0	0
Gulshan ravi b block	4	7	0	3
Gulshan colony	0	0	3	1
Gulshan ravi G block	3	22	2	2
Gurumanget	3	5	0	1
Gwala colony harbanspura	14	17	1	1
Huma block flats	12	34	11	14
lchhramor	2	2	0	2
Iftikhar park	2	5	0	0
Islampura	11	17	2	7
Jafaria colony	2	7	0	1
Jahanzeb block	3	6	2	6
Jallo Park	0	0	0	0
J-block johar town	2	5	0	0
Jnaz gah	5	12	0	0
Jubli town	0	0	0	0
Karim park	1	1	0	1
Khwaja ahmed sadiq	0	0	0	0
Kot khwaja saeed	2	5	0	0
Kot muhammad	1	4	0	0
Lahore college	0	0	0	0
Lall Pull	7	15	4	9
Liberty marker	4	18	0	1
Lahari gate	4	12	0	4
Masti gate	4	12	2	5
Mehmood booti	12	23	3	11
Mian fazal haq colony	0	1	0	0
Model colony	3	1	0	0
Mohalla islam Khan	2	2	0	0
Moman pura	2	4	0	1
Moon market gulshen	9	1	1	0
Mohari gate	22	26	1	2
Muslimabad Fateh gar	0	12	1	2
N block model town	1	4	0	2
Nabi bakish park	2	5	1	3
Naisar bagh	0	0	0	0
Nawankot samanabad	2	3	0	1
Nehru park	11	13	2	1
New jail road near PEC	0	0	0	0
Nishter colony	1	3	1	0
Nishter colony 2	0	0	0	1
Old anarkali	4	12	2	5
Old ravi well centre	01	0	2	7
Pak block	3	21	2	2
Pak mint	12	29	0	1
Pakki thatti	5	12	2	5
Pani walatalab	2	5	1	12
Patiala ground	0	1	0	1
Pindi Rajputan	7	13	1	3
Punjab cooperative	0	1	0	0
Q block	1	1	1	4
Quaid e millat collony	2	2	3	5
Race cource road	11	14	0	0
Residential colony pu	0	0	0	0
Salam atpura no 5	5	9	0	1
Salam atpura tkia	2	3	0	1
S-Block bahar colony	2	2	2	1
Shadman market	2	6	1	1
Shadman nala	1	14	1	7
Shah gohar pir	2	5	0	0
Shah kamal	0	1	0	1
Shahuwari	11	23	0	0
Shalimar garden	17	23	5	9
Shahuwari gate	22	42	0	1
Shish mehal	1	1	0	1
Sirajpura	3	5	2	3
Taj bagh scheme	0	12	0	1
Tajpura ground	1	1	4	1
Tariq colony maqbol	0	1	0	0
Taxali gate	5	11	0	1
Thokar niaz beg	1	1	0	1
Usman block	3	6	0	1
Vc office pu	0	0	0	0
WASA colony nawan k	2	3	0	0
Windsor park	1	4	0	0
Yakki gate	24	35	2	2
Zafar ali road	6	7	4	6

TW= Tube wells

Contiued in column 2

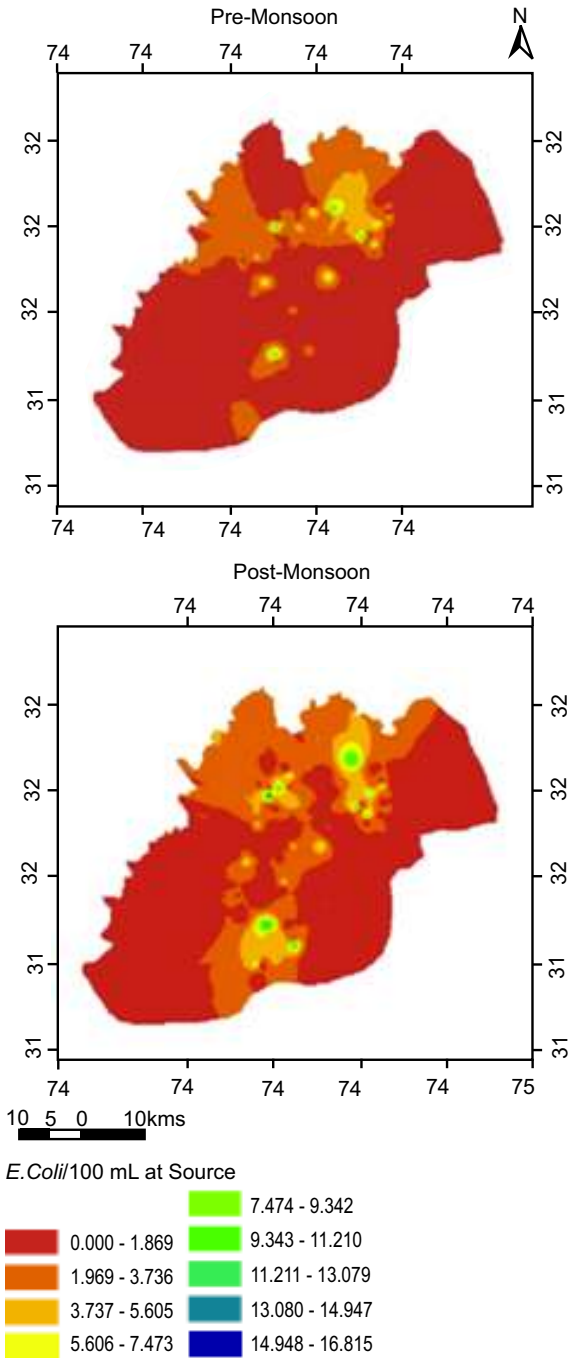

Fig. 2. Pre & post monsoon patterns of *E.coli* at source (2016).

Shadman ChahMiran, Gulshen Ravi, BaghMunshi Ledha, Ghaziabad, Taj Bagh, Lal Pull, Dars Bary Mian, Shalimar Garden, Mehmood Booti, Nala, Pindi Rajputen, Ahmed Block, KotLakhpat, Sirajpura, Pak Mint, S-Block Bahar Colony, Green Town, 6-AII Township, Chandni Chowk, C-Block Faisal Town, Nishter Colony, Daroghawala, Gwala Colony Harbanspura, 3-DII Township and Muslimabad.

Figure 2 also reflects the post-monsoon patterns of *E.coli*. which was detected in all samples of water except water samples of some areas like Badami Bagh, Dhobi Ghat, Lahore College, Q-Block Model Town, Momen Pura, Windsor Park, KotKhwaja Saeed, Iftihkhar Park, Jubli Town, Nasir Bagh, Modal Colony, Wasa Colony Nawaankot, Janazgah, F-n-V Market, J-Block Johar Town, Green Town, Patiala Ground, Gulshen Colony, Khwaja Ahmad Sadeq, Bagrian, Quaid-i-Millat Colony and Mian Fazal-e-Haq Colony. It was present in rest of all water samples of all locations. It was detected at many locations in post monsoon season where it was not detected in pre-monsoon season.

Figure 3 highlights patterns of *E.coli* at the end points in pre-monsoon season. *E.coli* was detected in water samples of those sites where it was also detected in water samples of tube wells such as Baghechi, Lahori Gate, Bilal Park, Yaki Gate Sheranwala Gate, Paniwala Talab, Akbari Gate, Masti Gate, Begumpura,Texali Gate, Paki Thati, Taj Pura, KotKhwaja Saeed, ChahMiran, Gulshen-e-Ravi, Bagh Munshi Ladha, Ahmad Block, Ghaziabad, TajBagh, Muslimabad, Mehmood Booti, Sirajpura, Shadman Nala, Green Town, Pak Mint, Kot Lakhpat, Lal Pul, Pindi Rajputan, Dars Bary Mian, Nishter Colony, S-Block Bahar Colony, 6-AII Township, Akbar Shaheed road, C Block Faisal Town, Daroghawala, Gwala Colony Harbenspura, Shalimar Garden, Chandni Chowk and 3 DII Township. *E.coli* was also detected in water samples of 16-B-1 Block Phatniwala, D Block Green Town, Begrian, Quaid-i-Millat Colony, Amer Sidhu Phatak, Race Course Road,Gulestan Colony Mustafabad, Gwala Colony, Model Colony, Zafer Ali Road , Gwala Colony Harbenspura, Sahuwari, Ichhra Mor, Janazgah, Nawankot, Shah Gohar Pir, Pak Block, Gulshen Block, Jahanzeb Block, Paki Thati, Shadman Market, Windsor Park, G-4 Johar Town, Momanpura, Salametpura No-5, Tajpura, Data Negar, Mohala Islam Khan, Badami Bagh, Karim Park, Nehru Park and Shalimar Garden. An increase in number of *E.coli* can be observed at sample locations of tube wells as well as end points in pre-monsoon seasons. It is quite clear at many tube well sites where *E.coli* was not detected but it was detected at end points. It highlights that water pipes that supply water were either not clean and were having sporadic mixing of sewage in drinking water. It is because of corrosion of both pipes.

A depression cone that is present in Centre of the district has also been reason of inclusion of salinity from the southern part of the district as well as addition of microbial and chemical pollution from River Ravi. Therefore, the sewage that mixes with groundwater and easily seeps down to aquifer and becomes part of groundwater. Afterwards, this water is extracted for drinking purposes.

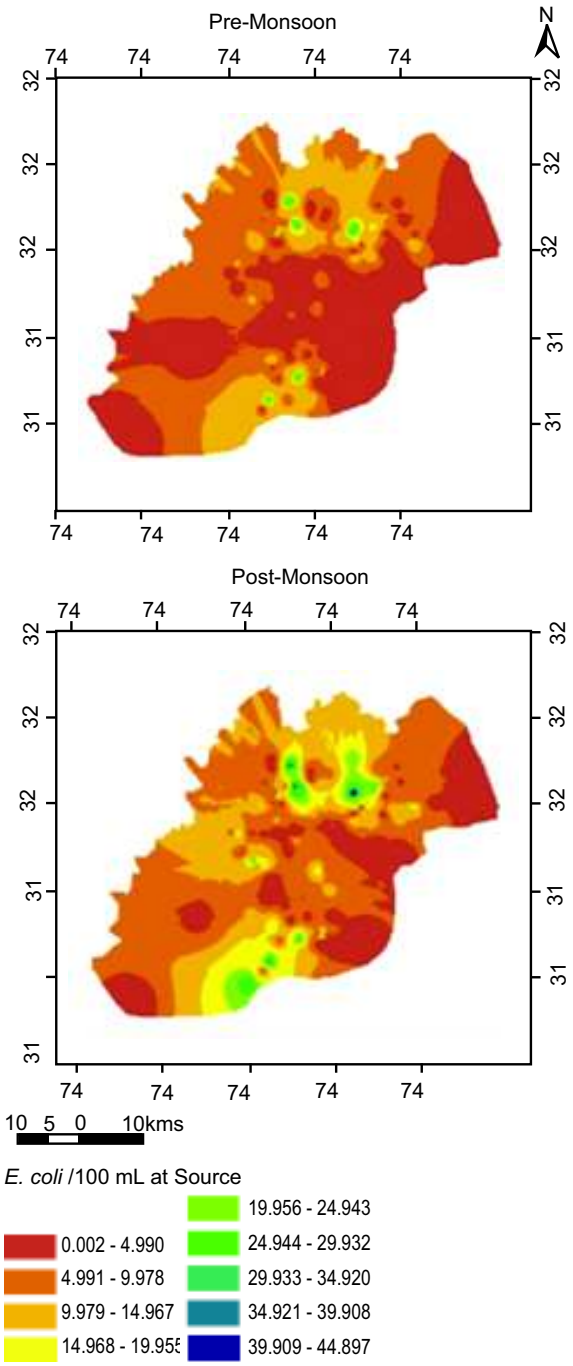

Fig. 3. Pre & post monsoon patterns of *E. coli* at end points (2016).

A few locations such as Lal Pull, Mughal Pura, Sheranwala Gate, Dars Bary Mian, Paniwala Talab, Ichra, , Liberty Market, Ahmed Block, Pindi Rajputan, Akbari Gate, General Hospital, Dhobi Ghat, Fatah Garh, Paki Thati Salametpura Takia, Baghichi, Bilal Park, Mori Gate, Zafar Ali Road, Dhobi Mandi, Bagh Munshi Ladha, Al-Faisal Town Burji, Fateh Garh, Lahore College, Tajpura Scheme, Dry Port, Tajpura Ground, Karem Park, Old Ravi Well Centre, Janazgah, Shadman Nala, Shadman Market, Shalimar Garden, Bagh-Gul Begum, Windsor Park, Salamatpura No-5, F-and-V Market, Gulshan-i-Ravi B block, Akbar Shaheed Road, Pak Mint, Gwala-Colony Harbanspura, Green Town, Township, Nishter Colony, Gulshen Colony, Beghrian, D-Block Green Town and Chandni-Chowk Township where water was much more polluted at sample end points than water of sample tube wells. The prime cause of pollution at those sites was the mixing of waste water from sewage collecting pipelines to water supplying pipelines. There were also a few locations where *E.coli* was not detected in water samples of tube wells but it was detected in water samples of end points.

Figure 3 also highlights the post-monsoon patterns of *E.coli* in water of sample houses. An increase in *E.coli* colonies was also noticed in post-monsoon period due to favorable climatic conditions for their growth at all the above mentioned end points during pre-monsoon season. It was also identified that *E.coli* was not detected at many places in water samples of tube wells in post-monsoon season but it was detected in water samples of end points. The major reason of prevalence of *E.coli* in water samples of houses was the mixing of sewage and public water supply due to old pipe lines.

Figures 4-5 show the trend of *E.coli* in different seasons. The trend was shown by using ellipses of standard deviation. It is a common way for measuring direction of a data to compute standard distance in three dimensions.

It creates a new class of features that is containing an elliptical polygon which is centered on the mean centre for all the features of the field. Figures 4-5 with standard deviation ellipses are showing two standard deviation ellipses in each figure. The ellipse in yellow hue reflects the distributional trend of *E.coli* in pre-monsoon season. The ellipse with red outline reflects trend of *E.coli* in post-monsoon season.

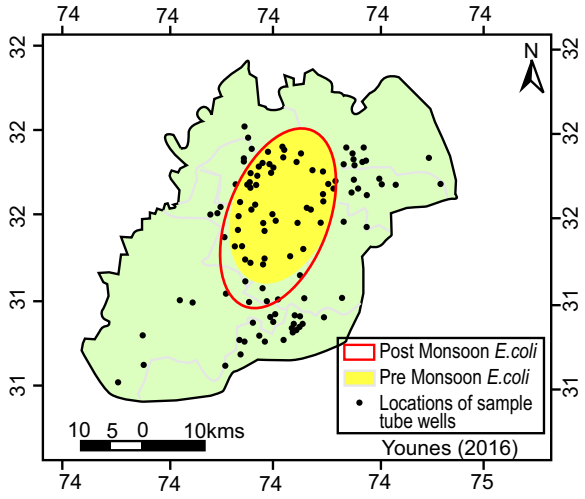

Fig. 4. Distributional trend of *E.coli* at tubewells

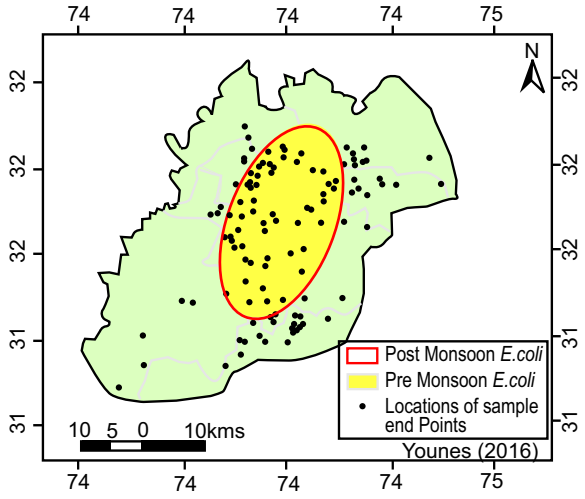

Fig. 5. Distributional trend of *E.coli* at end points

Figures 4-5 highlight the difference in distribution of *E.coli* in pre and post monsoon seasons in water samples of tube wells and end points. It is evident from Fig. 4 that *E.coli* were found in the centre of study area in pre-monsoon season in water of tube wells but in post-monsoon season its spread can be seen in southward direction.

Table 2 shows the correlation among diarrhoea and *E.coli* in pre and post monsoon season. It shows that there is a very strong and significant correlation among *E.coli* and diarrhoea during pre-monsoon season. It is also clear from Table 2 that the correlation between *E.coli* in post-monsoon season and diarrhoea is highly significant and shows the stronger relationship. Figure

Table 2: Correlation: diarrhoea, *E.coli*-Pre-monsoon, *E.coli*-Post monsoon

	Diarrhoea	E.coli-Pre-Monsoon		
E.coli-Pre-monsoon	0.863		0.000	
E.coli-Post monsoon	0.890	0.967	0.000	0.000

Cell Contents: Pearson correlation
P-Value

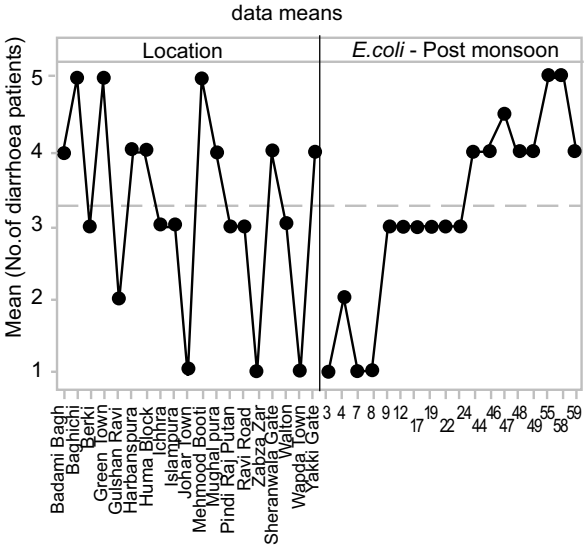

Fig. 6. Presence of *E.coli* and patients of diarrhoea

6 shows the presence of colonies of *E.coli* and patients of diarrhoea at different sample sites in study area. It is quite clear from the figure that the of patients of diarrhoea were large at those locations where numbers of colonies of *E.coli* were more.

Conclusion

Lahore is the second largest populated city of Pakistan. Most of the population of the city depends on public water supply system for drinking purpose. In this research it has been identified that *Escherichia coli* was detected in drinking water that is supplied by Public water supply system (WASA). It has also been pointed out that inhabitants of study area are suffering from diarrhoea caused by the presence of *E. coli* in drinking water. There were a few locations of end points where public water supply was more polluted with *E.coli* than water of tube wells. The major reason was the direct

addition of sewage from sewage pipes into water supplying pipes as both the pipes were very old and rusted. The regulatory authority WASA maintains and monitors the supply of public water in different parts of the city, yet it lacks proper implementation of rules as far as regular testing of water quality is concerned. It has also failed in changing pipes after regular interval through which public water is supplied.

Recommendations

- Industries need to treat their sewage on regular basis before disposing it off into River Ravi.
- In future, the depth of tube wells needs to be more than 700 feet to the east of the District.
- Regular testing of quality of water and water supplying lines need to be done by responsible authority.
- A broad maze of unlined waste water drains is found in Lahore that cause leakage of water from these drains into shallow unconfined aquifer which needs to be addressed at priority.

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