A systematic review on shifting trends of foodborne diseases in Pakistan

Sahar Munir¹, Syeda Hafsa Ali¹*, Syeda Ayesha Ali²

¹Department of Microbiology, Baluchistan University of Information Technology Engineering and Management Sciences, Quetta, Baluchistan, Pakistan
²Department of Biochemistry, Sardar Bahadur Khan Women University, Quetta, Balochistan, Pakistan

Abstract

Foodborne diseases are increasing at an alarming rate, thereby eliciting constant threat to public health worldwide. Approximately, 200 foodborne cases are caused due to ingestion of contaminated food each year. In developing countries, unhygienic practices are main reasons for foodborne diseases. Precise estimate of population-based data on food borne illnesses are scarce in Pakistan. This review focuses to elucidate etiological cause of foodborne diseases dominant in Pakistan from 1990 to 2018. Various databases were searched, and 88 articles related to foodborne diseases were identified. Around 59 articles were included on quality assessment criteria. We determined dominant pathogens associated with foodborne diseases among all provinces of Pakistan. High numbers of foodborne diseases were reported in Sindh. Whereas, Salmonella was determined as primary cause of foodborne ailments. Most of the reported data on antibiotic resistance was unavailable. Shigella spp were first reported for antibiotic resistance in 1990, and E. coli was reported for multi-drug resistance in 1998. Nevertheless, S. aureus was reported for Methicillin-resistant in 2015-16. This study summarize various sources responsible for food-borne illness, of which unhygienic conditions, poor sanitation systems, lack of proper infrastructure and continuous influx of refugees plays key role in escalation of morbidity rate in the region. We emphasize need of active surveillance system in reducing foodborne outbreaks in future and enable policy makers to set appropriate goals in food safety area.

Keywords: Food control, drug resistance, food safety, Pakistan

1. INTRODUCTION

Foodborne illnesses are infections of gastrointestinal (GI) tract which arises from improper handling, preparation, or food storage. Foodborne illnesses are major risk factors of morbidity and mortality around the world, affected by consumption of food polluted with pathogens, toxins and chemicals. According to WHO, foodborne diseases are mounting up at an alarming rate, causing significant impediment to socio-economic development of a country. Food based outbreak causes mortality of 2.2 million that contributes 4% of all deaths each year worldwide². Around, 75% of diarrheal cases are associated with pathogenic...
contamination of food. Around 1,500 million worldwide cases of diarrhoea occur annually, contributing 3 million deaths among children under five. Pakistan—among primitive stages of nutrition transition faces crucial public health concerns as these outbreaks go unreported due to poor surveillance system. Whereas, globalization of food supply, street vendors, growing influx of refugees, open sewages, poor sanitation and hygiene facilitate wide dispersal of microbes into the environment amplifies the concern. Approximately, 97% of foodborne illnesses emanate due to unhygienic handling, storage, and preparation of food that stimulate growth of pathogenic microorganisms. Large proportion of community have living standards below poverty line, with undeveloped infrastructure, open sewages, damp places, unhygienic living, and polluted environment that intensifies foodborne issue. Furthermore, sewage-contaminated municipal water is commonly used for irrigation of crops even in metropolitan areas. Lack of public policy, and equipment to maintain good hygiene are economic misfortunes associated with poor food security framework in Pakistan. Thus, all these practices promote foodborne disease. Lack of awareness regarding these harmful pathogens has led to rise in mortality and morbidity in Pakistan.

Although, indispensable efforts are required to determine causes of foodborne outbreaks at regional level. Lack of evidence on etiological factors, morbidity and mortality data has demanded need to improve hygienic and quality practices. Several studies reveals diverse factors are responsible for high incidence rate of foodborne diseases. This research illustrates key factors involved in foodborne diseases occurring in Pakistan from 1990 to 2018. We compiled published data on foodborne illnesses and its reported pathogens from all provinces of Pakistan. To emphasize need of active surveillance system to enable policy makers to prevent future outbreaks.

2. MATERIALS AND METHODS

2.1 Search strategy and criteria

We analyzed data on foodborne pathogens and its associated illnesses in Pakistan. A total of 59 articles were assessed that comprised of cross-sectional, case reports, cases studies, cohort studies, reviews, descriptive surveys of foodborne diseases. Relevant data published from June, 1990 to September, 2018 were included in this study comprising of bacterial species, protozoans and viruses responsible for foodborne diseases in different cities of Pakistan. The data was searched from July to October, 2018. Foodborne illnesses instigated by foodborne microbes included: Salmonella, Staphylococcus aureus, Clostridium botulinum, Shigella, Campylobacter jejuni, Clostridium perfringes, Escherichia coli, Vibrio, Listeria monocytogenes, Bacillus subtilis, Bacillus cereus, Cryptosporidium parvum, Toxoplasma gondii, Giardia spp., Entamoeba histolytica, Norovirus, Astrovirus, Hepatitis virus, Aspergillus, Penicillium, Mucor. Common outcomes related to pathogen based foodborne diseases were: food poisoning, cramps, diarrhoea, cold and chills, fever, headache, vomiting, nausea, dysentery, abdominal pain, dehydration, weakness, trouble breathing, headache, fatigue, bloating, gas or flatulence, and weight loss. Our study focused on the etiological factors of foodborne diseases and its associated incidence rate occurring each year. Published articles were hand searched and obtained from electronic databases such as: Google Scholar, Wiley Online library, JSTOR, Science Direct, NCBI, PubMed, World Health Organization (WHO) and JIDC. Additionally, we reviewed national surveillance data via national and international websites namely World Health Organization, Agha Khan University, Center for Disease Control and Management to extract facts and figure regarding foodborne illnesses in Pakistan. The retrieved articles included major cities of Pakistan (Karachi, Islamabad, Rawalpindi, Quetta, Gilgit, Lahore, Mardan, Chitral, Peshawar, Skardu, Multan, Hyderabad, Buner and Tandojam).

2.2 Inclusion and exclusion criteria

Two investigators screened all relevant data based on title, abstract, or full-text articles according to inclusive criteria. Relevant information was extracted from each article and reviewed independently by the investigators to validate the inclusions and remove duplicate articles. We included studies comprising of causative agents particularly bacteria, protozoa and viruses responsible for foodborne diseases, its
resistance to drugs, sources of illness, symptoms, region and year for incidence rate was reported. We excluded data that were restricted to waterborne illnesses, mortality rates and, disability adjusted life years of foodborne illnesses due to unavailability of data. The precise structure of research strategy is shown in Fig 1.

![Fig. 1. Search strategy and inclusion criteria](image)

A total of 66 relevant articles were identified on cause of foodborne illness in Pakistan reported from 1990 to 2018. After thorough screening only 59 articles were included in this study on the basis of study criteria.

### 2.3 Risk of biases and data processing

Around 88 articles were reviewed, yet 59 articles qualified the inclusive criteria. The included studies were hospital-based with higher rate of foodborne pathogens, lab based with focus on unhygienic food responsible for foodborne illnesses, rest were surveys of general population identified with food poisoning. The source of foodborne for pathogenic species included: raw vegetables, raw and cooked rice, uncooked meat, fish, and smoked beef. Similarly, to minimize sample specific materials were engrossed.

### 3. RESULTS AND DISCUSSIONS

This research determines core reasons for foodborne diseases in Pakistan, and provides deeper understanding of true association between this disease and conditions that promote growth of these causal pathogens. This research is first ever to recuperate rising concerns and provide better approach to diminish foodborne disease from our society. Consumption of unhygienic foods is core reason of foodborne diseases reported from 1990 to 2018. Together, 12 bacterial infections were responsible for 46 food hazards, 5 viral infections responsible for 6 epidemics, and 3 protozoans responsible for 7 foodborne infections causing number of cases, deaths, and asymptomatic carriers in last 28 years. These pathogens were identified as core cause of foodborne illnesses in Pakistan such as: *Salmonella* spp., *Staphylococcal* spp., *Clostridium* spp., *Shigella* spp., *Cryptosporidium* spp., *Listeria monocytogens*, *Bacillus* spp., *Vibrio* spp., *Escherichia* spp., including protozoans such as: *Toxoplasmosis gondii*, *Giardia* spp., *Entamoeba histolytica* and viruses like *Noroviruses*, *Astroviruses* and *Hepatitis virus* (See Table 1). Majority of foodborne cases in developing countries go unreported, due to lack of active surveillance system. Moreover, humid environmental conditions support microbes under optimum conditions. Contamination, poor sanitation, lack of
medication and resources are main contributing factors for annual morbidity rate of foodborne illnesses in Pakistan. *Salmonella* spp., *T. gondii* *Campylobacter* spp., and *Norovirus* were accountable for highest morbidity rates, whereas, *L. monocytogenes, T. gondii* and *Norovirus* caused high proportion of mortality. We found high incidence rate of foodborne illness caused by *Salmonella*, where many infections are asymptomatic. Latest serologic evidence from Europe also suggested that common cause of foodborne disease is *Salmonella* spp. Our data lacked mild illnesses associated with foodborne pathogens due to lack of registered cases. Botulism is a serious flaccid illness contracted by ingestion of contaminated food or polluted water. Previous research shows that mild cases of botulism are often associated with outbreaks, but affected persons seldom seek medical care. Recently, botulism outbreaks have intensified with 1,000 cases occurring annually due to consumption of potent neurotoxins in unhygienic foods. *C. botulinum* is resistant to penicillin and metronidazole. Similarly, *L. monocytogenes* is recognized as cause gastroenteritis and fever, though hardly identified by routine stool test.

Pakistan being high burden country contributes an annual incidence rate of 413 per 100,000 populations (Raza et al., 2014). A food that contains *Salmonella* includes crude or half-cooked eggs, unpasteurized milk, polluted water, and or uncooked meats. Poor sanitation and sterile conditions are predisposing factors responsible for 21 million cases and 21,000 fatalities annually. Of these, 80% of cases happen in Asia alone. Resistance of *Salmonella* spp., to antimicrobial medications are now prevalent in both developed and developing nations. The burden of staphylococcal infection, predominantly by methicillin resistant *S. aureus* strains (MRSA) has increased worldwide. Generally, *S. aureus* bacteremia (SAB) has incidence rate of 20 to 50 cases per 100,000 populations each year in Pakistan.

*S. typhi* and *Hepatitis E virus* are the prominent reported cases from Quetta, Baluchistan. Baluchistan has a dry and extreme weather and that may affect the proliferation of foodborne pathogens. Likewise, in summer the temperature in this area may rise up to 50°C, which may permit food spoilage. It is the largest province in terms of land, yet deprived zone having no access to clean water, improper sewage, aseptic conditions, unhygienic food production, lack of proper infrastructure with continuous influx of refugees. *Salmonella* is common in children reported in different hospitals with 18.6% prevalence rate.

The economic status in KPK is equal to Baluchistan, the same structure gap exists, contributes to wide range of foodborne diseases. *Giardiasis* was observed among children from 4 to 14 years in Peshawar, where lack of hygiene, poor sewage system, congestion, and low financial status were witnessed as risk dynamics. *Hepatitis E virus* from various cites of KPK was reported along with *Amebic* dysentery with prevalence *E. histolytica* higher (33.8%) among children and lower in adults (15.3%). In 2010, Pakistan experienced floods and consequently cholera outbreak with large number of cases associated with *Vibrio cholera O1*. A food that contains *Salmonella* includes crude or half-cooked eggs, unpasteurized milk, polluted water, and or uncooked meats. Poor sanitation and sterile conditions are predisposing factors responsible for 21 million cases and 21,000 fatalities annually. Of these, 80% of cases happen in Asia alone. Resistance of *Salmonella* spp., to antimicrobial medications are now prevalent in both developed and developing nations. The burden of staphylococcal infection, predominantly by methicillin resistant *S. aureus* strains (MRSA) has increased worldwide. Generally, *S. aureus* bacteremia (SAB) has incidence rate of 20 to 50 cases per 100,000 populations each year in Pakistan.

The results obtained from Gilgit Baltistan showed a large number of reported cases of *Salmonella typhi* during spring season (5%) trailed by summer (4.5%) and harvest time (2.17%), while no *S. typhi* invasion was recorded in winter. High proportions of individuals face public hazards due to poor sanitation practices. Shigellosis is one of the common gastroenteritis diseases occurring more often in summer. *Toxoplasma gondii*, cases were reported in northern areas and of particular concern in women by causing abortion and pre-mature birth or inherent abnormalities in new born children 24.7% prevalence rate reported in Chitral showing. *Toxoplasma gondii* caused maximum cases of toxoplasmis in individuals are contracted by digestion of infected meat having tissue cysts. Toxoplasmis prevalence of ranges from 11.33% to 29.45% in Pakistan. Infection peaks in hot, humid climates as oocysts survives better in these environment. Where, *T. gondii* showed resistance towards azithromycin, spiramycin and sulfadiazine. *Cryptosporidium parvum* is significant cause of diarrhea in infants and its incidence is considerably high in Gilgit and Skardu.

Foodborne pathogens reported from Sindh included: *Salmonella typhi, Staphylococci aureus, Campylobacter jejuni, Shigella spp. S. dysenteriae, S. flexneri, S. boydii and S. sonnei, Vibrio cholera O, Vibrio cholera O139, Clostridium botulinum, Giardia duodenalis, Entamoeba histolytica, Norovirus, Astrovirus and Hepatitis E virus*. Carrier rate of typhoidal *S. enterica* serovars in food handlers working in
different food streets of Karachi is outrageous. Food handlers might be contributing to high prevalence of typhoid cases in Karachi, Pakistan\textsuperscript{14}. Poor sanitation and sterile conditions are major inclining factors\textsuperscript{29}. In a hazard analysis of food items \textit{S. aureus} and MRSA were found in high proportion due to unhygienic conditions during handling, processing and packaging. Food handlers are significant source of staphylococcal dissemination. Despite the fact the hotspot for staphylococcal prologue to food stuffs was not followed out—questioning the nourishment security and policy makers on customer wellbeing\textsuperscript{27}. In Pakistan \textit{S. aureus} is found resistant to vancomycin and tetracyclines, doxycycline\textsuperscript{27}. Moreover, Cholera cases are highly reported in Sindh due to improper sanitary practices. The incubation period of \textit{V. cholera} is short term and cholera-related diarrhea occurs suddenly and causes watery fluid, nausea and vomiting which may persist for hours at a time and dehydration. \textit{Vibrio cholera} is reported for resistant against tetracycline, ampicillin, kanamycin, streptomycin, and trimethoprim-sulfamethoxazole\textsuperscript{1}.

Pakistan has large proportion of cases instigated due to faecal contamination prompted with transmission of enteric pathogens through water, sustenance, human and creature. Consequently, gastroenteritis remains a noteworthy reason for loose bowels among pediatric population of our country. In Pakistan, self-medication and consumptions of drugs without a recommendation are commonly practiced. Thus, there is a larger likelihood of development of resistant isolates due to over use of antibiotics\textsuperscript{28}. In developing countries, \textit{Campylobacter} infection frequently occurs in children, where asymptomatic infection are more common\textsuperscript{29}. Predominance of the \textit{C. jejuni} are astounding in chickens (6 \%), sheep (5 \%) and cow (1 \%)\textsuperscript{30}. This pathogenic organism is developing resistant to antibiotics, especially fluoroquinolones and macrolides\textsuperscript{31}.

\textit{Shigella} is major cause of acute dysentery in children. According to CDC 450,000 yearly episodes of shigellosis occur in United States\textsuperscript{32}. Food associated with \textit{Shigella} outbreak involves contaminated hand contact during preparation. Once inside host, bacteria causes lysis of cell membranes, and reinitiate intracellular replication to disseminate into the epithelium. \textit{Shigella} species, were vulnerable to ampicillin, nalidixic acid, co-trimoxazole and chloramphenicol. However, recently they have established resistance against fluoroquinolones, cephalosporins and azithromycin. Moreover, insufficient knowledge regarding resistant strains to treat shigellosis is an ultimate challenge in Pakistan\textsuperscript{28}. Movement of numerous strains with antibiotic resistance is alarming and demands active surveillance to facilitate control of shigellosis\textsuperscript{33}. \textit{L. monocytogenes} infection has global mortality rate of 20-30\% \textsuperscript{34}. \textit{Listeria} is typically transmitted via contaminated food or water. Approximately, 20 to 30\% of foodborne infections in immunocompromised individuals may result in fatality. \textit{Listeria} spp., are vulnerable to antibiotics except cephalosporin, nalidixic acid, oxacillin and clindamycin\textsuperscript{30}. Moreover, high percentages of \textit{E. coli} O157:H7 and \textit{Listeria monocytogenes} in milk are root cause of foodborne illnesses\textsuperscript{35-36}.

\textit{Giardia lamblia} is a protozoan parasite of small digestive tract that causes major number of morbidity globally. Infection is initiated by ingestion of contaminated water with few cysts adequate to cause disease\textsuperscript{37}. Antimicrobial resistance is observed against furazolidone\textsuperscript{17}. \textit{Entamoeba histolytica} infects 50 million individuals with mortality rate of 55,000 individuals’ annually worldwide\textsuperscript{38}. An investigation conducted in Konkor, Gadap, District Karachi, determined 48.86\% \textit{Entamoeba histolytica} are responsible for diseases. Factually socio-economic factors were found unrelated, while age and immunity were found correlated to initiation of disease\textsuperscript{37}. Transmission occurs via ingestion of contaminated food and water polluted with \textit{E. histolytica} cysts\textsuperscript{37}.

\textit{Norovirus} and \textit{Astrovirus} standout amongst as well-known cause of intense gastroenteritis among children in developing countries. \textit{Astroviruses} are known causative agents of gastroenteritis since 1975, with fluctuates predominance rate in Asia between 10–30\%\textsuperscript{39}. \textit{Norovirus} causes intense gastroenteritis among children in undeveloped countries. \textit{Noroviruses} causes morbidity of 267,000,000 cases annually around the world. However, prevalence rate are under reported in Pakistan \textsuperscript{40}. No information on the predominance and hereditary fluctuation of \textit{norovirus} are accessible for Pakistan, where early youth mortality because of intense gastroenteritis is common. This report affirms presence of different \textit{norovirus} genotypes in hospitalized kids with intense gastroenteritis in Pakistan\textsuperscript{40}.

This review identified causal agents of foodborne diseases, which was particularly high in Karachi due to high influx of patients. Consequently, due to advanced treatments or overcrowding that disseminates the diseases more commonly. Second being the largest province with population is Punjab where high rates of foodborne pathogens were isolated. Followed by KPK, Gilgit and Balochistan, where low income, low populace, refugee influx, lack of proper sewage systems thrived the diseases and most of which remain unreported. The largest factor in contributing the food borne ailments were lack of hygiene and resistance to antibiotics. Furthermore, self-medication without a prescription and over use of antibiotics are important factors responsible for development of resistant strains.

**Table 1.** Foodborne diseases in Pakistan from 1990 to 2018.

<table>
<thead>
<tr>
<th>Causative agent</th>
<th>Specimen</th>
<th>Sample size</th>
<th>Incidence/prevalence rate</th>
<th>Year</th>
<th>Location</th>
<th>Antibiotic resistance</th>
<th>Study design</th>
<th>Refere nce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shigella spp.</td>
<td>Faecal sample</td>
<td>152</td>
<td>Not available</td>
<td>1990</td>
<td>Lahore</td>
<td>Ampicillin, nalidixic acid, cotrimoxazole</td>
<td>Case study</td>
<td>28</td>
</tr>
<tr>
<td>Astrovirus, Norovirus, Sapovirus</td>
<td>Faecal sample</td>
<td>517</td>
<td>11.2%, 9.9%, 3.2%</td>
<td>1990-1994</td>
<td>Karachi</td>
<td>Not available</td>
<td>Cohort study</td>
<td>41</td>
</tr>
<tr>
<td>Vibrio cholerae</td>
<td>Faecal sample</td>
<td>886</td>
<td>97%</td>
<td>1990-96</td>
<td>Karachi</td>
<td>Not available</td>
<td>Case study</td>
<td>42</td>
</tr>
<tr>
<td>Staphylococcus aureus, coliforms, Staphylococcal enterotoxin type A</td>
<td>Milk-based Confectioneries</td>
<td>200g</td>
<td>Not available</td>
<td>1991</td>
<td>Islamabad</td>
<td>Not available</td>
<td>Hazard analysis</td>
<td>43</td>
</tr>
<tr>
<td>Staphylococcus aureus, Clostridium perfringens, Bacillus cereus, Staphylococcus aureus, Salmonella</td>
<td>Food items</td>
<td>13 food items</td>
<td>Not available</td>
<td>1992</td>
<td>Islamabad</td>
<td>Not available</td>
<td>Hazard analysis</td>
<td>44</td>
</tr>
<tr>
<td>Campylobacter jejuni</td>
<td>Faecal sample</td>
<td>52,77 7</td>
<td>24.8%</td>
<td>1992-2002</td>
<td>Karachi</td>
<td>Ampicillin; tetracycline and ofloxacin</td>
<td>Cohort Study</td>
<td>45</td>
</tr>
<tr>
<td>Salmonella typhi</td>
<td>Food, water</td>
<td>100 cases</td>
<td>36%</td>
<td>1994</td>
<td>Karachi</td>
<td>Not available</td>
<td>Case control study</td>
<td>46</td>
</tr>
</tbody>
</table>
### Hepatitis E virus
- **Polluted water**: 600
- **Not available**: 1995
- **Peshawar, Mardan, Abbottabad, Islamabad, Sargodha, Multan, Hyderabad, Quetta and Karachi.**
- **Cross sectional study**: 47

### Shigella dysenteriae, Shigella flexneri, Shigella boydii, Shigella Sonnei
- **Faecal specimen**: 1573
  - **0%, 54.4%, 10%, 39%**: 1996-2007
  - **Karachi**
  - **Ampicillin, trimethoprim**, 
  - **Sulfamethoxazole, nalidixic acid, ofloxacin**
  - **Cohort Study**: 48

### Salmonella typhi
- **Faecal specimens**: 585
  - **3.6%**: 1997-1999
  - **Gilgit**
  - **Cefotaxime, ceftriaxone, ciprofloxacin and enoxacin.**
  - **Cohort study**: 20.

### Shigella spp.
- **Faecal specimens**: 585
  - **13.2%**: 1997-1999
  - **Gilgit**
  - **Chloramphenicol, nalidixic acid, ampicillin, ceftriaxone, cefotaxime, ciprofloxacin and enoxacin.**
  - **Cohort study**: 21

### E coli O157:H7
- **Urine**: 1000
  - **73.1%**: 1998
  - **Lahore**
  - **Multi drug resistance**
  - **Cross sectional Study**: 49

### Vibrio cholera O1
- **Blood, faecal sample**: 8
  - **Not available**: 1998-2008
  - **Pakistan**
  - **None**
  - **Case study**: 50.

### Vibrio cholera O139
- **Faecal Sample**: 550
  - **Not available**: 2000-2001
  - **Karachi**
  - **None**
  - **Case study**: 51
<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Type of sample</th>
<th>Prevalence</th>
<th>Year</th>
<th>Location</th>
<th>Antimicrobials</th>
<th>Study Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salmonella typhi</em></td>
<td>Blood sample</td>
<td>3671</td>
<td>2001-2006</td>
<td>Karachi</td>
<td>cotrimoxazole, chloramphenicol and ampicillin</td>
<td>Cohort study</td>
</tr>
<tr>
<td><em>Salmonella paratyphi A</em></td>
<td>Blood sample</td>
<td>160</td>
<td>2002</td>
<td>Tandojam</td>
<td>Not available</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td><em>E. coli O157:H7</em></td>
<td>Raw milk</td>
<td>160</td>
<td>2002</td>
<td>Tandojam</td>
<td>Not available</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td><em>Entamoeba histolytica</em>, <em>Giardia lamblia</em></td>
<td>Faecal sample</td>
<td>263</td>
<td>2002</td>
<td>Karachi</td>
<td>Not available</td>
<td>Cross sectional study</td>
</tr>
<tr>
<td><em>Campylobacter jejuni</em></td>
<td>Faecal sample</td>
<td>100</td>
<td>2002</td>
<td>Rawalpindi</td>
<td>Not available</td>
<td>Cohort study</td>
</tr>
<tr>
<td><em>Shigella spp.</em></td>
<td>Faecal sample</td>
<td>4688</td>
<td>2002-2003</td>
<td>slums of Karachi</td>
<td>Ofloxacin, ceftriaxone, Cotrimoxazole, nalidixic acid, ampicillin</td>
<td>Cross-sectional study</td>
</tr>
<tr>
<td><em>Campylobacter jejuni</em>, <em>Food items and brewages</em></td>
<td>Faecal sample</td>
<td>1636</td>
<td>2002-2004</td>
<td>Faisalabad, Lahore and Islamabad</td>
<td>Not available</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>Meat</td>
<td>40</td>
<td>2003</td>
<td>Faisalabad</td>
<td>Not available</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td><em>Giardia lamblia</em></td>
<td>Faecal sample</td>
<td>239</td>
<td>2004-2006</td>
<td>Peshawar</td>
<td>Not available</td>
<td>Cohort study</td>
</tr>
<tr>
<td><em>Norovirus</em></td>
<td>Faecal sample</td>
<td>255</td>
<td>2006-2008</td>
<td>Karachi, Lahore, Rawalpindi</td>
<td>Not available</td>
<td>Case report</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>Bovine milk</td>
<td>200</td>
<td>2007</td>
<td>Hyderabad</td>
<td>Cotrimoxazole, erythromycin, penicillin (Oxoid)</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td><em>Not available</em></td>
<td>Sign and symptoms</td>
<td>110</td>
<td>2007</td>
<td>Military training center</td>
<td>Not available</td>
<td>Outbreak</td>
</tr>
<tr>
<td>Pathogen/Agent</td>
<td>Study Type</td>
<td>Sample Type</td>
<td>Sample Size</td>
<td>Year(s)</td>
<td>Location(s)</td>
<td>Treatment/Resistance</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>----------------</td>
<td>-------------</td>
<td>-------------</td>
<td>---------</td>
<td>----------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Shiga toxin–producing Escherichia coli (STEC)</strong></td>
<td>Case study</td>
<td>Faecal sample</td>
<td>23</td>
<td>2007</td>
<td>Faisalabad</td>
<td>Ampicillin</td>
</tr>
<tr>
<td><strong>Cryptosporidium parvum</strong></td>
<td>Cohort study</td>
<td>Faecal sample</td>
<td>200</td>
<td>2007-08</td>
<td>Peshawar</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Cryptosporidium parvum</strong></td>
<td>Descriptive study</td>
<td>Polluted water</td>
<td>300</td>
<td>2007-08</td>
<td>Gilgit</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Salmonella typhi and Salmonella paratyphi, Salmonella spp</strong></td>
<td>cohorts study</td>
<td>Not available</td>
<td>2532</td>
<td>2007-11</td>
<td>Lahore</td>
<td>Ciprofloxacin, Ampicillin and Cotrimoxazole</td>
</tr>
<tr>
<td><strong>Shigella flexneri, Shigella sonnei, Shigella boydii, Shigella dysenteriae</strong></td>
<td>Surveillance study</td>
<td>Faecal sample</td>
<td>8155</td>
<td>2008</td>
<td>urban slums of Karachi</td>
<td>Cotrimoxazole, ampicillin</td>
</tr>
<tr>
<td><strong>Astrovirus</strong></td>
<td>Case report</td>
<td>Faecal sample</td>
<td>535</td>
<td>2009-10</td>
<td>Rawalpindi</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Klebsiella, Enterobacter, Staphylococcus aureus and Bacillus subtilis</strong></td>
<td>Hazard analysis/Experimental study</td>
<td>Raw meat samples and surface swabs from meat processing equipment</td>
<td>340</td>
<td>2010</td>
<td>Karachi</td>
<td>Ampicillin, amoxicillin, novobiocin and cefaclor</td>
</tr>
<tr>
<td><strong>Vibrio cholera 01</strong></td>
<td>Cross sectional</td>
<td>Faecal sample</td>
<td>319 (not available)</td>
<td>2010</td>
<td>Sindh, Punjab and Khyber Pakhtunkhwa</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Salmonella enteritidis, Salmonella typhi, Salmonella pullorum, Salmonella typhimurium</strong></td>
<td>Surveillance study</td>
<td>Broiler chicken meat</td>
<td>100 samples</td>
<td>2010</td>
<td>Hyderabad</td>
<td>Ampicillin</td>
</tr>
<tr>
<td><strong>Entamoeba histolytica</strong></td>
<td>Cross sectional study</td>
<td>Faecal sample</td>
<td>234 patients</td>
<td>2011</td>
<td>Slums of karachi</td>
<td>Not available</td>
</tr>
<tr>
<td>Pathogen</td>
<td>Sample Type</td>
<td>N</td>
<td>Prevalence</td>
<td>Year</td>
<td>Location</td>
<td>Treatment/Investigation Method</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------------------------</td>
<td>------</td>
<td>---------------</td>
<td>--------</td>
<td>----------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>Fruits/vegetables</td>
<td>29</td>
<td>10%</td>
<td>2011</td>
<td>Mardan</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Salmonella typhi</strong></td>
<td>Blood sample</td>
<td>2964</td>
<td>18.6%</td>
<td>2011-2012</td>
<td>Quetta</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Escherichia coli</strong> (Pathotypes, enterotoxigenic EC)</td>
<td>Flooded water sample</td>
<td>200</td>
<td>33%, 50%</td>
<td>2011-2012</td>
<td>KPK province</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Campylobacter jejuni</strong> (C. jejuni)</td>
<td>Diarrheal cases of poultry, cattle and humans</td>
<td>436</td>
<td>35%, 25%, 11.3%</td>
<td>2011-12</td>
<td>Islamabad</td>
<td>Cephalothin, sulfamethoxazole+trimethoprim, Ampicillin, Beta-lactamase</td>
</tr>
<tr>
<td><strong>E. coli, S. aureus, Salmonella</strong></td>
<td>Food items</td>
<td>91</td>
<td>25.5%, 16.6%, 11.1%</td>
<td>2012</td>
<td>Islamabad</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Salmonella Typhi, Salmonella paratyphi</strong></td>
<td>Blood</td>
<td>2</td>
<td>(not available)</td>
<td>2013</td>
<td>Karachi</td>
<td>nalidixic acid, ampicillin, chloramphenicol and cotrimoxazole</td>
</tr>
<tr>
<td><strong>Entamoeba histolytica</strong></td>
<td>Faecal sample</td>
<td>316</td>
<td>23.1%</td>
<td>2013</td>
<td>Buner</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Klebsiella spp., Enterobacter spp., Enterococcus spp., Staphylococcus aureus</strong></td>
<td>Salad</td>
<td>50</td>
<td>16%, 11%, 13%, 7.5%</td>
<td>2014</td>
<td>Lahore</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Clostridium perfringes</strong></td>
<td>Meat</td>
<td>300</td>
<td>6%</td>
<td>2014</td>
<td>Lahore</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Cryptosporidium parvum</strong></td>
<td>Faecal sample</td>
<td>53</td>
<td>20.8%</td>
<td>2014-2015</td>
<td>Skardu</td>
<td>Not available</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>Pathogen</th>
<th>Sample Type</th>
<th>Sample Size</th>
<th>Prevalence</th>
<th>Year</th>
<th>Location</th>
<th>Antimicrobial Treatment</th>
<th>Study Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>63.</td>
<td><em>Salmonella enteritidis</em></td>
<td>Broilers</td>
<td>150</td>
<td>23.3%</td>
<td>2014-15</td>
<td>Kohat</td>
<td>Ampicillin, tetracycline, augmentin, chloramphenicol</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td>64.</td>
<td><em>Bacillus subtilis</em></td>
<td>Cooked and Raw Rice</td>
<td>168</td>
<td>52, (raw rice)</td>
<td>2015</td>
<td>Lahore</td>
<td>Not available</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td>64.</td>
<td><em>Bacillus cereus</em></td>
<td>Cooked and Raw Rice</td>
<td>168</td>
<td>38%(raw rice), 46%(cooked rice)</td>
<td>2015</td>
<td>Lahore</td>
<td>Not available</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td>65.</td>
<td><em>Bacillus alvei, Bacillus subtilis, Bacillus polymyxa, Pseudomonas aeruginosa, Staphylococcus aureus, Klebsiella pneumonia, Escherichia coli and Enterobacter</em></td>
<td>Unpasteurized packed fruit juices</td>
<td>60</td>
<td>Not available</td>
<td>2015</td>
<td>Lahore</td>
<td>Not available</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td>66.</td>
<td><em>Shiga toxin-producing E. coli pathotypes</em></td>
<td>Salad</td>
<td>260</td>
<td>34 %</td>
<td>2015</td>
<td>KPK</td>
<td>Tetracycline, Ampicillin</td>
<td>Hazard analysis</td>
</tr>
<tr>
<td>67.</td>
<td><em>Salmonella Enterica serovars</em></td>
<td>Street food</td>
<td>220</td>
<td>9.1%</td>
<td>2015</td>
<td>Karachi</td>
<td>sulfamethoxazole+trimethoprim, Ampicillin</td>
<td>Cross-sectional study</td>
</tr>
<tr>
<td></td>
<td><em>Bacillus spp., Staphylococcus aureus, Escherichia coli, Aspergillus spp., Saccharomyces cerevisiae, Penicillium sp. and Rhizopus</em></td>
<td>Fruit juices</td>
<td>90</td>
<td>Not available</td>
<td>2015</td>
<td>Lahore</td>
<td>Not available</td>
<td>Hazard analysis</td>
</tr>
</tbody>
</table>
4. CONCLUSIONS

We have reviewed prevailing foodborne pathogens and its associated diseases from 1990 to 2018 among all provinces of Pakistan on the basis of reported cases, incidence rate, source of disease and antibiotic resistance. We conclude that overall environmental conditions in Pakistan are humid providing optimum conditions to microbes for their survival. Contamination, poor sanitation, fewer resources and lack of medication are the key factors to elicit foodborne infections in the regions. *Salmonella* spp., *Campylobacter* spp., and *T. gondii* induces most hospitalizations, while *Norovirus* stimulates high mortality rates. Moreover, misuse of antibiotics pose greater challenge in developing new strategies to counter antimicrobial resistance. Therefore, scientific community are actively involved in investigating novel bioactive compounds against resistant microbes. This research utilizes prevalent rates of foodborne diseases to provide directions to policymakers’ in predicting annual burden in future. We recommend active surveillance system to report food safety issues and burden of foodborne illnesses to provide better approach emphasizing to eradicate foodborne disease from our society.

CONFLICT OF INTEREST

All the authors claim that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGMENT

The authors are grateful to management of BUITEMS for providing the facilities to do the research work.

REFERENCES


This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License. To read the copy of this license please visit: https://creativecommons.org/licenses/by-nc/4.0/