Iran J Public Health, Vol. 54, No.10, Oct 2025, pp.2263-2274

Original Article

Epidemiological Study and Time Series Modeling of Waterborne and Foodborne Disease Outbreaks in Northwestern Iran: 2016-2023

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(Received 19 Feb 2025; accepted 18 May 2025)

Abstract

Background: Outbreaks of waterborne and foodborne illnesses arise from the consumption of contaminated food or water. Factors contributing to these outbreaks include improper food storage, inadequate hygiene during food preparation, and environmental contamination. This descriptive-analytical study aimed to investigate the epidemiology and time series modeling of waterborne and foodborne disease outbreaks in West Azerbaijan Province from Jan 2016 to Dec 2023.

Methods: Data recorded in the health deputy's portal system were utilized for analysis. The variables examined included age, sex, number of patients, hospitalizations, fatalities, presenting symptoms, and spatial and geographical data related to the outbreaks. Box–Jenkins models were employed for time series analysis. Descriptive statistics were computed using SPSS 26 software, while modeling was conducted using R Studio 2021.09.2 and Minitab 22.2.1 software

Results: During the study period, 1306 outbreaks were reported, resulting in 2686 cases of illness, 792 hospitalizations, and 7 fatalities. The causative agent of waterborne and foodborne outbreaks was identified through laboratory testing in 43% the cases. Entamoeba histolytica (31%) was the most commonly identified pathogen, followed by *E. coli* (27%), and *Shigella* (18%). The most common locations of outbreaks were in cities (57.9%) and at home (86.9%). The ARIMA(0,0,0)(1,0,0)12 model was determined to be the most effective model for predicting future cases.

Conclusion: Water- and foodborne diseases pose a significant threat due to their rapid spread, with incidence rates increasing from 5.25 per 100,000 (2016) to 9.51 per 100,000 (2023). Fruits, juices, meat, and drinking water were primary contamination sources. Public education on food handling and safe water access are crucial for reducing disease transmission.

Keywords: Outbreaks; Waterborne and foodborne diseases; Time series

DOI: https://doi.org/10.18502/ijph.v54i10.20144

Introduction

Water and foodborne diseases represent significant challenges to public health. Despite advancements in food hygiene, these diseases persist (1). Innovations in food technology, lifestyle changes, bulk purchasing of food items, prolonged storage of refrigerated foods, and inadequate knowledge concerning food hygiene, including storage and cooking methods, have contributed to the increasing incidence of waterborne and foodborne outbreaks (2). It is estimated that 7.7% of people around the world experience foodborne illnesses annually, with a mortality rate of 7.5%. Waterborne diseases account for approximately 485,000 diarrheal deaths each year (3).

The CDC defines an outbreak of waterborne and foodborne illnesses as a scenario in which two or more individuals exhibit similar symptoms of illness after consuming contaminated water or food (4). Identifying the origin of contamination plays a critical role in investigating disease outbreaks and implementing preventive measures. Diseases arising from water and food are associated with specific sources, linking illnesses caused by the consumption of contaminated food or specific substances to as a crucial element in assessing food safety risks (5). Effective management and implementation of control measures are essential for enhancing food safety and public health and as well as for preventing waterborne and foodborne diseases in similar situations in the future (6).

Waterborne diseases result from the consumption of or contact with water contaminated by pathogenic microorganisms. Such diseases can rapidly proliferate within communities, leading to widespread outbreaks that threaten public health (7).

The literature describes multiple methods for analyzing waterborne and foodborne outbreaks. These encompass microbiological analyses of clinical and food samples, exposure assessments, case-control studies, and epidemiological investigations of both sporadic and outbreak cases, along with surveillance data review (8). Due to the lack of comprehensive data in many developing countries, which often lack precise monitoring and reporting systems for recording and analyzing diseases, research tends to focus more on prevalent illnesses. Consequently, there are fewer studies on rare or emerging diseases, and many investigations overlook the influence of social, economic, and cultural factors on the prevalence food borne and waterborne diseases. Furthermore, insufficient collaboration among various fields, such as public health, food supply chain, and environmental health, results in informational and analytical gaps (9)

Therefore, identifying risk components and gaining a better understanding of the patterns of prevalence and the risk factors associated with food- and waterborne diseases, along with developing prevention and control strategies based on scientific data and research in this field, is essential for improving public health. Additionally, these efforts can contribute to the establishment of sustainable and effective systems for ensuring community health (10,11).

New approaches are needed to analyze water- and foodborne disease outbreaks in West Azerbaijan Province, considering its unique challenges. The region's border location, diverse climate, and demographic structure require tailored strategies (12). Insights from this research will guide preventive measures and policy decisions, improving public health locally and nationally. Advanced data analysis is essential for predicting outbreaks and enhancing water and food safety interventions (13). Therefore, this study aimed to investigate the epidemiological characteristics of outbreaks and their temporal trends through time series analysis in West Azerbaijan Province from 2016 to 2023. This research sought to identify the specific sources of contamination in food, outbreak locations, and influential factors to anticipate future events. These findings are critical for formulating proactive measures to control and prevent outbreaks originating from water and food supplies.

Materials and Methods

Study Design

A descriptive-analytical approach was adopted to investigate the epidemiological characteristics and temporal trends of waterborne and foodborne disease outbreaks in West Azerbaijan Province, covering the period from Jan 2016 to Dec 2023.

Data Source and Population

The study utilized data from the Health Department's portal system, comprising all reported outbreaks occurring in the province during the specified years. All cases registered in this portal formed the study population.

Variables

Collected data included demographic characteristics (age, sex), number of affected individuals, hospitalizations, fatalities, clinical symptoms, geographical location, and the main setting of each outbreak, determined by either assumed site of exposure or where the implicated food was handled or consumed. Information regarding the suspected food item was also recorded.

Data Collection and Processing

All relevant data were extracted and coded, then systematically entered into SPSS for descriptive statistical analysis.

Statistical Analysis and Time Series Modeling

For temporal analysis, monthly outbreak data were organized as a time series and examined for trends and seasonality. Stationarity was assessed using Box-Cox and Dickey-Fuller tests, with transformations and seasonal differencing applied as needed. ARMA/ARIMA models were selected based on autocorrelation patterns and AutoARIMA, with final model adequacy evaluated using residual analysis and the Akaike Information Criterion (AIC). Analyses were performed using R Studio and Minitab. (14, 15).

Inclusion and Exclusion Criteria and Data Limitations

This study included all reported waterborne and foodborne disease outbreaks in West Azerbaijan Province from Jan 2016 to Dec 2023 with complete records and clearly identified sources, excluding duplicates and incomplete entries. Data were obtained from routine health reporting systems, which may lead to underreporting, especially of milder cases or in remote areas. The accuracy of outbreak details depends on the quality of initial local health reports, so these limitations should be considered when interpreting the findings.

Ethical Considerations

This study used anonymized, secondary data and received approval from the relevant ethics committee. No personal identifiers were collected or reported.

This study was approved with the code of ethics (IR.UMSU.REC.1402.257) at Urmia University of Medical Sciences.

Results

Descriptive Analysis

Throughout the study period, there were 1306 reported outbreak cases, resulting in 2,686 individuals being affected by the disease, with 54% being female and 46% male. Among these cases, 792 (60%) individuals required hospitalization, and there were 7 fatalities (3 males and 4 females). The average outbreak rate during the study period was 5.25 per 100,000 individuals, with a minimum rate of 2.41 in 2021 and a maximum rate of 9.51 in 2023. During the 8-year research period, Shahin Dezh and Maku Counties experienced the highest and lowest incidence rates of 96.3 and 15.71 cases per 100,000 people, respectively (Fig. 1). The age group most affected was 5 to 20-year-olds, accounting for 23.2% of the cases. The 21 to 30-

year age group comprised 17% of the cases, while those over 60 yr old represented the lowest percentage at 4.7%. Notably, 13.5% of the cases were individuals under 5-year-old.

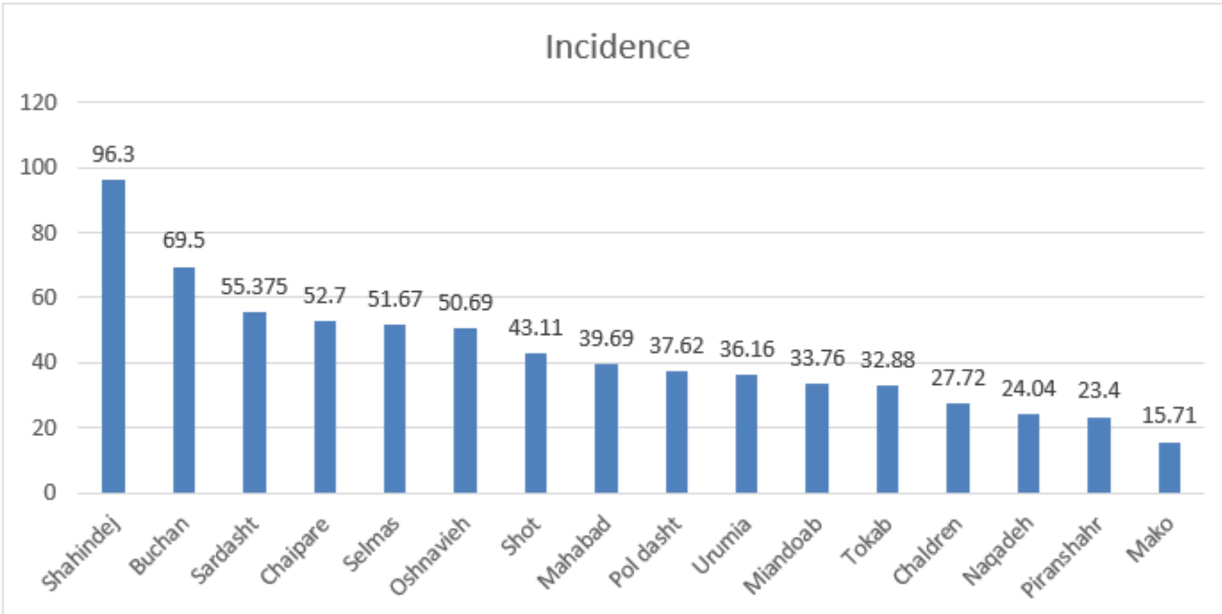

Fig. 1: Incidence rates of waterborne and foodborne disease outbreaks across cities in Northwestern Iran, 2016-2023

In 57.9% of the instances, outbreaks occurred in town areas (An urban area is defined as a zone characterized by high population density and developed urban infrastructure), whereas 86.9% of the outbreaks originated from home settings, with 1.6% traced back to daycare centers and 3% at unspecified locations. Food or water consumed by patients was tested in a mere 43% of the investigated cases. The tested samples mainly consisted of water, likely because food items are often not available for testing or are not preserved adequately. Analysis of these 43% of samples revealed Entamoeba histolytica (31%), *E. coli* (27%), and *Shigella* (18%) as significant pathogens. Symptoms among affected individuals varied, with 47.5% experiencing diarrhea and vomiting and 28.7% presenting solely with non-bloody diarrhea. Instances of double vision and blurred vision were documented in 0.1% of the patients, whereas a decreased level of consciousness was observed in 0.8%. Food poisoning was attributed to the consumption of a specific food item in 80.3% of the cases. Notably, the highest rates of food poisoning were associated with fruits and fruit juice (22.6%), barbecue, and meat dishes (21.9%). Drinking water is also 10.5%. Conversely, fish and seafood consumption accounted for the lowest incidence of food poisoning, at 0.4% (Table 1).

Statistical Modeling

This study analyzed monthly time-series data, revealing a clear trend. Cases initially rose slightly in 2016 before declining through late 2018. The lowest point (76 cases) occurred in 2021, followed by an upward trend peaking at 299 cases in 2023. Seasonal patterns showed lower rates in early months, a spring increase, summer peaks (Jun-Aug), and a fall decline. Residual analysis after removing trends and seasonality showed no discernible patterns (Fig. 2).

Table 1: Abundance of waterborne and foodborne disease outbreaks by location, place of occurrence, causative pathogen, symptom, and type of food consumed in Northwestern Iran, 2016-2023

Variable	Type	N	%	Variable	Type	N	%
Location	Town	757	57.9	Place of Occurrence	Homemade	1135	86.9
	Village	549	42		Restaurant/Cafe/Fast food	42	3.21
Causative pathogen	Entamoeba histolytica	167	31		Celebrations/Religious ceremonies	43	3.29
	Escherichia *coli*	156	27		Hospital / Barracks / Dormitory	22	1.68
	Shigellosis	104	18		Kindergarten/School/ University	21	1.6
	Clost botulinum	28	5		Unknown	43	3.1
	Salmonella	27	4.8	Type of food	Fruit and juice	296	22.6
	Cholera	15	2.6		Barbecue and broth	278	21.9
	Yeast	9	1.6		Salad, Vegetables, Poisonous mushrooms	234	10.2
	Other	54	9.6		Drinking water	138	10.5
Symptom	Bloody diarrhea	16	1.2		Milk/Dairy products	65	4.9
	Nonbloody diarrhea	375	28.7		Soup	63	4.8
	Diarrhea and vomiting	621	47.5		Sausage/Other fast foods	49	3.7
	Fever/Diarrhea /Vomiting/Abdominal pain	244	18.6		Rice/ and grains	69	5.3
	Abdominal pain/Concussion	25	1.9		Cakes and sweets	53	4
	Double nose/ Blurred vision	2	.1		Canned and compote	25	1.9
	weakness/lethargy	12	.9		fish and seafood	6	.4
	Loss of consciousness	11	.8		Other	121	9.2

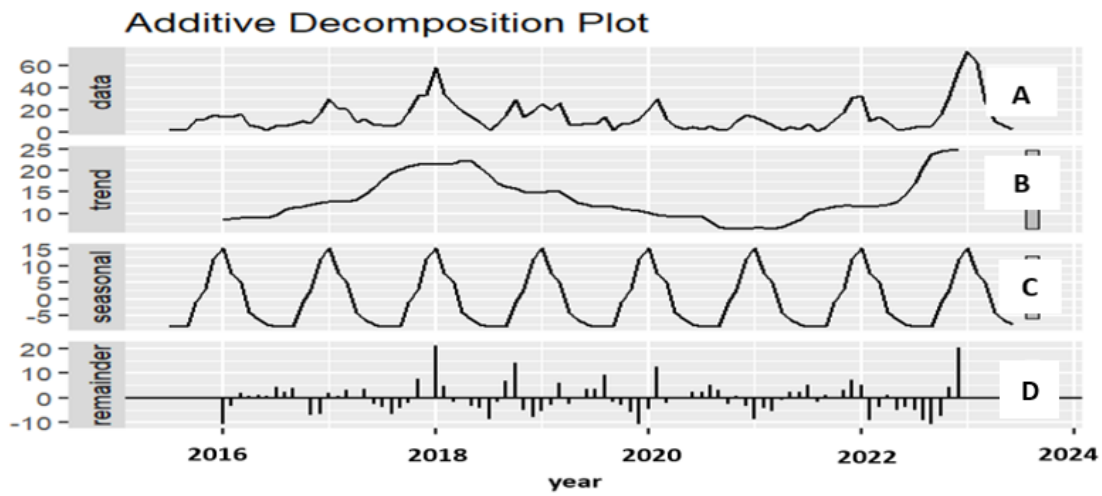

Fig. 2: Decomposing the components of the time series for waterborne and foodborne disease outbreak cases: trends, seasonality, and residuals

To perform a time series analysis, the data must be stable in terms of both variance and mean. Initially, the Box-Cox transformation was used to assess the stability of variance. The confidence interval did not include 1, indicating instability in variance (Fig. 3). Consequently, a logarithmic transformation was applied, resulting in stabilized variance. The stability of the mean was then evaluated on the data that had been stabilized in terms of variance. In this study, the trend presents in the data, as observed in the time series plot, was further supported by the autocorrelation function (ACF) plots, which do not approach zero over time, and the partial autocorrelation function (PACF) plots, indicating instability in the mean. Furthermore, the Dickey-Fuller test confirmed the presence of mean instability (*P*=0.543) (Fig. 3).

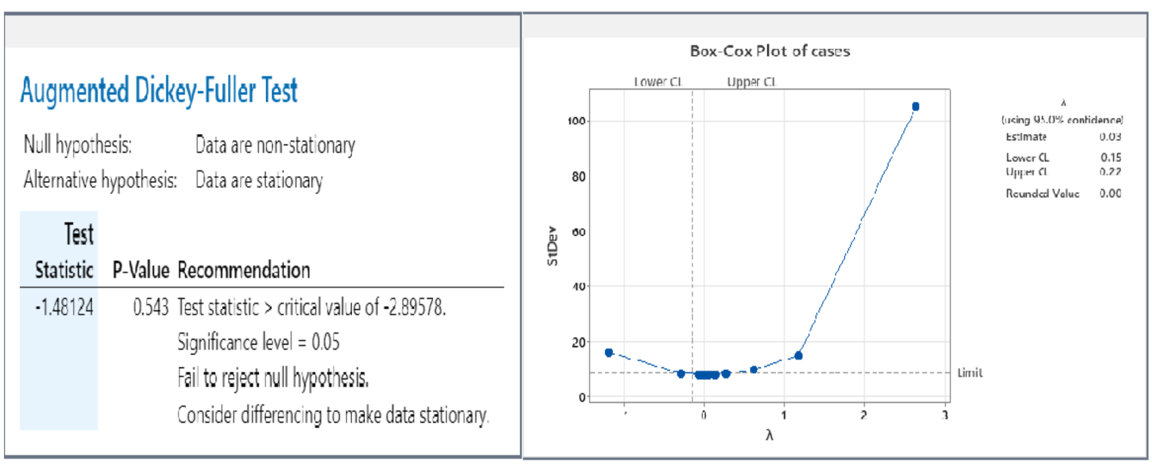

Fig. 3: Dickey–Fuller test and Box–Cox plot for assessing the mean and variance stability

To address the instability observed in the mean of the time series, we initially applied first-order differencing, followed by seasonal differencing, which resulted in a more stable dataset for analysis. Inspection of the ACF and PACF plots after seasonal adjustment provided guidance for selecting appropriate model parameters. The ACF plot revealed a notable spike at lag 4,

pointing to a significant seasonal pattern, and consequently, the seasonal autoregressive parameter (P) was set to 1. In contrast, no meaningful peaks appeared in the PACF plot, so the seasonal moving average parameter (Q) was set at 0 (Fig. 4).
For further validation, the "autoarima" function in R was used to compare candidate models based on criteria such as the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and log-likelihood. ARIMA (0,0,0)(1,0,0)12 ultimately demonstrated the most favorable fit, as reflected in the model selection statistics (Tables 2 and 3). Diagnostic checks showed that the residuals were free from significant autocorrelation and that the model assumptions were met, indicating that the chosen model is well-suited for describing and forecasting trends in waterborne and foodborne disease outbreaks.

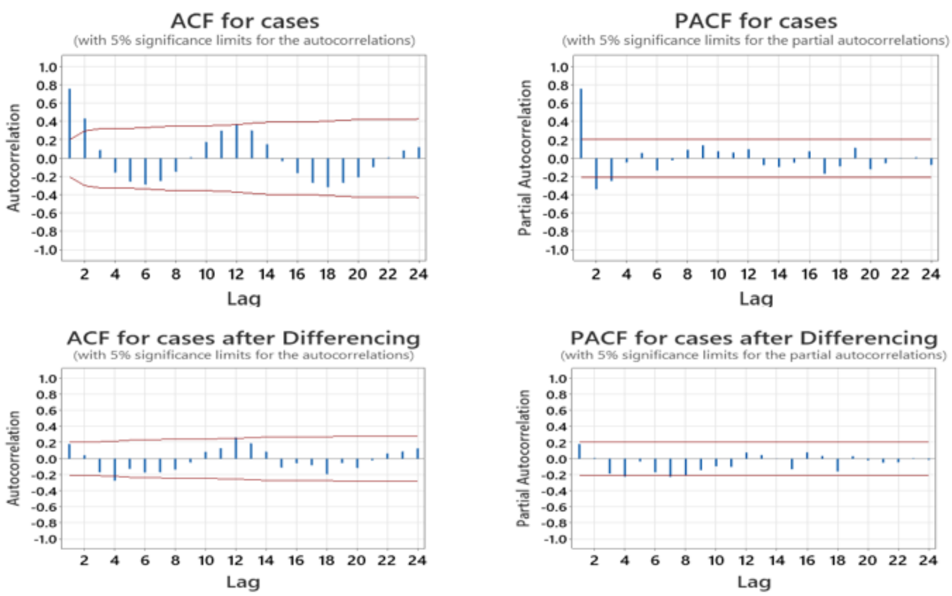

Fig. 4: Autocorrelation function (ACF) and partial autocorrelation function (PACF) before and after seasonal differentiation.

Table 2: Final estimates of parameters for the ARIMA (0,0,0) (1,0,0)12 mode

Type	Coef	SE Coef	T-Value	*P*-value
SAR 12	0.3491	0.1094	-4.93	0.000
Constant	5.654	0.821	6.89	0.000

Table 3: AIC, BIC, and log-likelihood criteria for the ARIMA (0,0,0) (1,0,0)12 Model

Log-likelihood	-341.42
AIC	686.85
BIC	691.96
AICc	686.98

Since some of the spikes in the autocorrelation and partial autocorrelation plots were statistically significant, in addition to the above model, several other models were evaluated by adding or removing model parameters to identify the most suitable model. These models, along with their AIC and log-likelihood indices, are presented in Table 4.

Table 4: Presents the examined ARIMA models along with their AIC and log-likelihood indices

Row	ARIMA Model	Log-likelihood	AIC
1	ARIMA(0,0,0)(1,1,1)	-349.83	666.32
2	ARIMA(1,0,0)(0,1,1)	-352.08	672.05
3	ARIMA(0,0,1)(0,1,0)	-347.37	682.45

Additionally, by examining the residuals of the model, (Fig. 5) the adequacy of the model was evaluated. In the ACF and PACF plots of the residuals, none of the lags were found to be significant. Panels A and B indicate the normality of the residuals. Moreover, the normality of the residuals was confirmed via the Kolmogorov–Smirnov test (*P*-value=0.137). As the residuals are approximately between two parallel lines, the assumption of homoscedasticity of residuals is established. Fig. 5 displays the distribution of residuals over time, showing no specific pattern and confirming the randomness of the residuals.

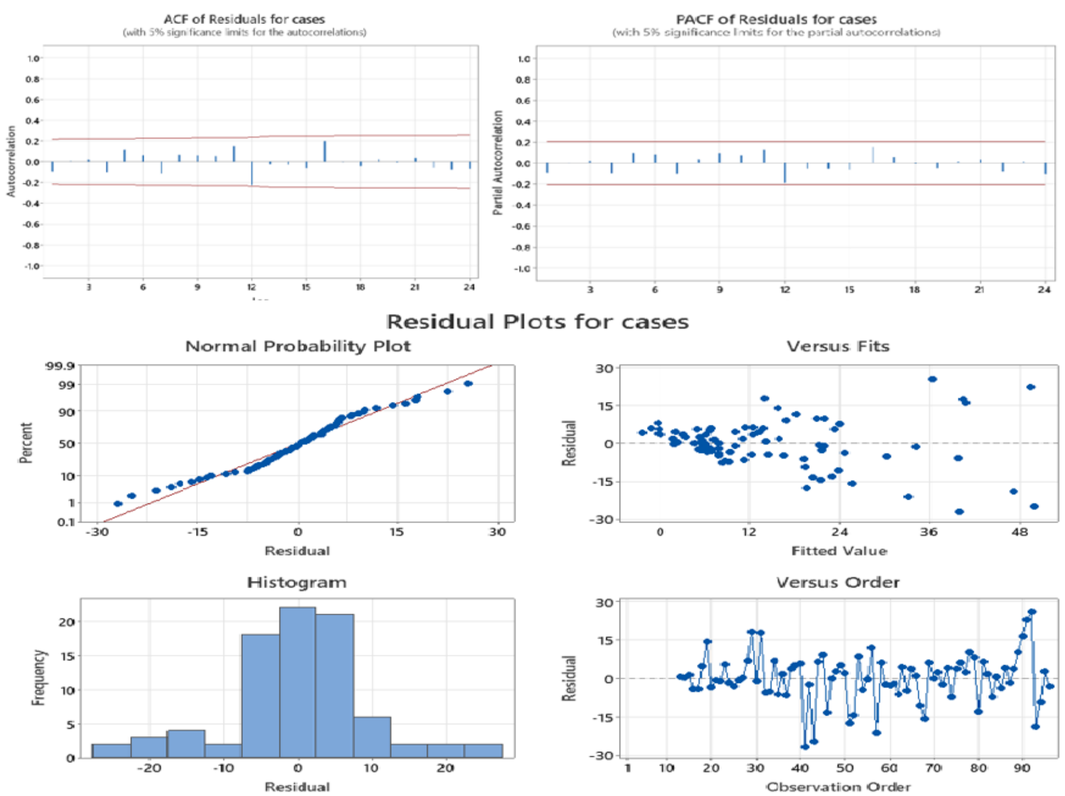

Fig. 5: Residual plots, autocorrelation function, and partial autocorrelation function of the residuals for the ARIMA (0,0,0) (1,0,0)12 model

Ultimately, the predicted outcomes for the next 6 months indicate a decrease in waterborne and foodborne disease outbreak cases and the continuation of the seasonal trend with a 95% confidence interval (Fig. 6).

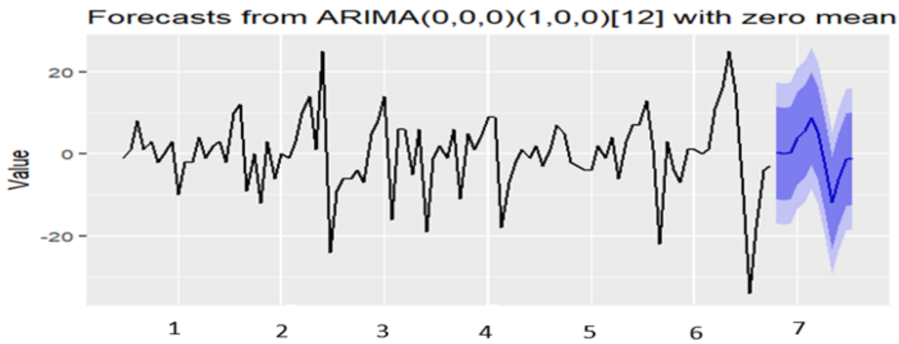

Fig. 6: Predicting Waterborne and Foodborne Disease Outbreak Cases via ARIMA (0, 0, 0) (1, 0, 0)12 for the Next 6 Months in Northwestern Iran, 2016-2023

Discussion

The current study revealed that the average incidence rate of waterborne and foodborne disease outbreaks during the study was 5.25 per 100,000 individuals, with a minimum of 2.41 and a maximum of 9.51 per 100,000 individuals. The frequency of occurrence was slightly greater in women than in men, and the age group of 5-20 and 21-30 yr had the highest frequency, which aligns with the findings of Ebrahimi's study in Kurdistan Province (16). These factors may include sociocultural influences, as well as biological factors such as the female immune system, particularly during phases such as pregnancy and lactation when immunity is compromised, making women more vulnerable to water and foodborne infections (17). The greater incidence of water and foodborne illnesses among younger populations may stem from a combination of increased exposure due to their more frequent involvement in household tasks, and underlying biological factors that heighten their susceptibility to such infections (16). This heightened participation in domestic activities can increase their encounters with pathogens, particularly if consistent hygiene measures are lacking. Furthermore, the adventurous eating habits of younger individuals, particularly among adolescents, can lead to the consumption of new or exotic foods that may not have been prepared or stored safely (9).

In this study, the causative agent was detected in 43% of the cases, with Entamoeba histolytica, E. coli, and Shigella being the most prevalent pathogens. In parallel studies, the causative agent was identified in 40% and 60% of cases, respectively (18, 19). Among the afflicted individuals, 47.5% presented symptoms of diarrhea and vomiting, whereas 27.8% presented solely with nonbloody diarrhea. Moreover, the toxins generated by these microorganisms can trigger intestinal inflammation and injury, along with disruptions in water and nutrient absorption, leading to manifestations such as diarrhea and vomiting (20). In 57.9% of the cases, the outbreak occurred in the city, and in 86.9% of the cases, the site of the outbreak was the home. The majority of cases occurred at home, followed by religious ceremonies and celebrations, and, outbreaks occurred at home, followed by restaurants and dining establishments (18, 21). The use of contaminated water for drinking and improper food storage at home, such as storage at inappropriate temperatures or for prolonged periods, can lead to an increase in the growth of bacteria and microorganisms in food. Inadequate cooking practices or a lack of awareness about hygiene and food preparation can result in diseases caused by the consumption of water and food contaminated at home (22). Additionally, the increase in the incidence of cases in urban areas can be due to changes in lifestyle, activities outside the home, the busy schedule of families, and the consumption of fast foods and packaged foods (23).

In 80.3% of cases, the cause of water- and food-borne outbreaks was the consumption of contaminated food. Among food items, the leading causes of food poisoning were attributed to the consumption of fruits, fruit juices (22.6%), kebabs, and meat dishes (21.9%). Fruits and vegetables accounted for 32.9%, and meat and meat dishes accounted for 20.9% of the highest causes of food poisoning (16). The primary cause was grains and legumes (2). Meat and meat dishes, as well as vegetables, were the leading causes of food poisoning (24). Meat and meat dishes spoil faster due to their protein content and environmental contamination, and a lack of adherence to hygiene standards and inadequate cooking can lead to the transmission of pathogens to humans. Owing to improper washing and storage, irrigation with contaminated water, and the predominant consumption of untreated water, can be the main cause of most food poisoning (25). Water safety and its impact on the quality of fruits and fruit juices is a specialized area within the field of public health and food safety. The quality of water, as a vital resource for agriculture—particularly in the irrigation of crops—must be subject to continuous monitoring (26).

The trend in the occurrence of food poisoning has gradually increased since the beginning of the study with a downward trend observed since late 2018, and in 2021, almost coinciding with the peak of COVID-19 spread, it reached its lowest level (76 cases). Subsequently, from early 2022, almost concurrently with the decline in COVID-19, the trend has been increasing, and in 2023, it reached the highest level of occurrence (299 cases). In South Korea, the incidence trend of water and foodborne outbreaks increased from 2015 to 2018, but the prevalence declined in 2019 (21). The mild increasing trend at the beginning of the study could be attributed to the rise in the culture of consuming restaurant food and improvements in healthcare systems and reporting. With the increase in the prevalence of COVID-19, the focus on personal hygiene and adherence to health guidelines intensified. The consumption of ready-made and restaurant foods decreased, and greater emphasis was placed on packaging and disinfecting food items (27). The reduced intensity of these factors during the COVID-19 pandemic may explain the differences in the prevalence of the disease during phases of COVID-19 spread and contraction. In general, comparisons of the trends in the occurrence of outbreaks between different regions are uncommon because of differences in lifestyle, adherence to personal hygiene and food safety practices, and the geographical and ecological characteristics of the region. Moreover, the frequency of occurrence has been increasing since April as temperatures rise, reaching peaks in June, July, and August, and subsequently decreasing in September. These patterns align with the findings of Bokaie (18), Shonhiwa (28), and Lu D (29). The increase in incidence during warmer months can be attributed to the conducive environment for bacterial and viral growth due to high temperatures and humidity. Notably, a mere 1-degree Celsius increase in temperature can result in an approximately 5% increase in the incidence of foodborne diseases of foodborne diseases (30).

Conclusion

This study reveals a concerning rise in water- and foodborne outbreaks, primarily involving Entamoeba histolytica, E. coli, and Shigella, especially in urban and household settings. Safe food handling and clean water access are crucial for prevention. Future research should explore risk factors and evaluate intervention effectiveness.

Limitations

The study had limitations, such as incomplete lab testing, potential underreporting in remote areas, and reliance on secondary data, which may impact accuracy. Results should be interpreted cautiously, and further research is needed.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

No financial source was received for this study.

Conflict of Interests

The authors have no conflicts of interest to declare.

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