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Ranking of the Ecological Disaster Areas According to Coliform Contamination and the Incidence of Acute Enteric Infections of the Population in Kyzylorda Region

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ABSTRACT

The paper is devoted to monitoring the environmental coliform bacteria (CB) contamination (soil and water) in the environmental disaster areas in the Kazakhstan part of the Aral Sea Region and ranking districts by their level of contamination and the rate of gastrointestinal infections (GI). The research was done in environmental disaster areas (Aral District, Kazaly District) and environmental crisis areas (Karmakshy District, Zhalagash District, and Shieli District) in the Kyzylorda Region. The areas were ranked in terms of CB contamination level and GI rate in descending order. The bacterial composition in the gathered water samples showed that the greatest number of contaminated samples was found in the Aral District and an insignificantly smaller number of contaminated water samples were found in the Shieli District. A combination of various microorganisms (by two or three species) was found in most studied samples of soil and water, while the total microbial count ranged from 2.1 to 6.7. The obtained results show that the rankings of areas by E.coli contamination and GI rate coincided or were very close, but weakly correlated with the severity of the environmental disaster.

KEYWORDS
Coliform bacteria, Gastrointestinal Infections, environmental disaster, water and soil pollution, Aral See

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Introduction

Inefficient and excessive use of water from the river basins of the Aral Sea during the past 40 years for agricultural irrigation purposes caused a rapid shrinkage of the water basin area, desertification or salinization of vast areas, and water shortage. All this deteriorated the living conditions and changed the economic status of the local population, its employment, income, labor

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conditions, and sustenance infrastructure. All this manifested in the rapid change in the public health of the Aral Region in general and the rate of gastrointestinal infections in particular (Abdullaev & Rakhmatullaev, 2013; Anuraj et al., 2015; Arora et al., 2014; Bain et al., 2014; Batabyal & Chakraborty, 2015; Bekchanov et al., 2015). Infectious agents that carry bacterial enteric infections and parasitic diseases, the biological cycle whereof includes a period of existence in the environment, where they can reproduce, are especially dangerous for people.

Due to the shrinkage of the Aral Sea and the desertification of vast areas, the Kazakh part of the Aral Sea Region has been declared an area of environmental disaster (Omarova et al., 2015). In terms of the environmental disaster severity, the Kyzylorda Region is divided into the following zones: environmental disaster (Aral District, Kazaly District) and environmental crisis areas (Karmakshy District, Zhalagash District, and Shieli District) (Bekchanov et al., 2015). The environmental situation changed the nature of economic activity in both the agricultural and industrial sectors (Abdullaev & Rakhmatullaev, 2013). The level of socioeconomic life has also changed (White, 2013). The standard of living largely determines the GI rate, the infections agents whereof are transmitted via contaminated water. However, public health in this region has not been studied comprehensively with regard to the level of environmental contamination and the severity of the environmental disaster.

Therefore, monitoring the environmental coliform bacteria (CB) contamination (soil and water) in the environmental disaster areas in districts and ranking said districts by their level of contamination and the rate of gastrointestinal infections was the purpose of this research.

Literature Review

Sanitary and Bacteriological Assessment of Soil

Soil is the main reservoir of microorganisms in nature (Lozupone et al., 2012). The qualitative composition of soil microflora is diverse (Glaser et al., 2015). The detection of pathogenic organisms is an indicator of epidemic danger; however, direct detection is related to a number of difficulties due to the low content of these microorganisms that can reproduce in water and soil (Charkowski et al., 2012). Sanitary and bacteriological practice uses techniques based on the assessment of the contamination level and detection of sanitary indicator bacteria (Prendergast & Kelly, 2012; Shen, 2012; Smyth et al., 2014).

Sanitary indicator bacteria belong to three tribes of the Enterobacteriaceae family (Brenchley & Douek, 2012). It is worth noting that the term CB is sanitary and bacteriological or environmental, not taxonomic. This group includes microorganisms of the Esherichia, Citrobacter, Enterobacter, and Klebsiella genera; their environmental features are the reason behind their indicator significance (Canton et al., 2012; Jacob et al., 2013). Detection of E.coli in environmental objects is a reliable indicator of fresh fecal contamination (Harwood et al., 2014). The presence of Citrobacter and Enterobacter in these objects is indicative of relatively old fecal contamination (Bain et al., 2014). Bacteria that belong to the Proteae tribe (for instance, Proteus vulgaris) of the Enterobacteriaceae family are common in nature (Crous et al., 2013). They are putrefaction bacteria and are found in large numbers in decomposing remains of animals and plants (Cablk, Szelagowski, & Sagebiel, 2012).

The presence Clostridia in the soil is indicative of fecal contamination, both fresh and old, since these bacteria generate spore and survive in soil for a long time (Heaney et al., 2012).

Thermophiles include Lactobacillus lactis, Streptococcus termophilus, and other bacteria that reproduce at a temperature of 60°C and higher (Guarner et al., 2012). They do not live in the human intestines constantly and do not serve as criteria of environmental fecal contamination (Monteagudo-Mera et al., 2012). Rapid increase in their count in self-heating manure and compost is indicative of soil contamination with decomposing waste (Sharma et al., 2014).

Sanitary and Bacteriological Assessment of Water

Water microflora reflects the microbial composition of the soil, since microorganisms mostly enter water via its particles (Jiang, Zheng & Chen, 2012). Certain biocenoses form in water with the prevalence of microorganisms adapted to their habitat conditions, light, oxygen and carbon dioxide solubility, and content of organic and mineral substances (Dang & Lovell, 2016). Various bacteria are found in fresh water: rod-shaped (Pseudomonas, Aeromonas), coccoid (Micrococcus), and coiled (Fester et al., 2014). Water contamination with organic substances is accompanied by an increase in the count of anaerobic and aerobic bacteria and fungi (Guarner et al., 2012).

Water transmission of infections has great epidemiological significance (Patel, Shrivastava & Patel, 2014). Water is a favorable living environment for many microbes, viruses, and protozoa (Strunz et al., 2014). This causes their long circulation in water, transfer over great distances, and reach of places of water use located far downstream of the contamination source (Mc. Mahon & Read, 2013). Microbial contamination of both underground and surface waterbodies occurs due to discharge of insufficiently treated wastewater into them, runoff from agricultural lands and animal husbandry facilities (Prüss-Ustün et al., 2014). Insufficiently treated and decontaminated wastewater of hospitals bear significant epidemiological danger (Temmerman et al., 2013). Fecal contamination of surface waterbodies is caused by discharge of domestic wastewater into rivers and other fresh waterbodies (Norman et al., 2013). Using such water without special treatment and contamination may cause an outbreak of a water-borne epidemic (Arora et al., 2014).

Drinking water from the system of centralized water supply, wells and streams (decentralized water supply), surface waterbodies (rivers, lakes, ponds), swimming pools, mineral water, and wastewater should be subject to sanitary and bacteriological examination (Mc. Mahon & Read, 2013). These examinations are carried out as part of the systematic monitoring of the quality of water from the system of centralized water supply by epidemic indicators or when choosing a water supply source (Kounina et al., 2013).

Drinking water quality monitoring requires regular sampling of both natural reservoirs and the water supply system (Anuraj et al., 2015). The presence of E.coli in water indicates fecal contamination and potential danger to public health (Escher et al., 2014) and serves as a warning to sanitary inspectors that the water may be contaminated with microorganisms that are more dangerous, for instance, dysentery bacillus, enteroviruses or hepatitis virus (Mc. Mahon & Read, 2013).

Problems of Drinking Water Supply in Environmental Disaster Areas in the Kyzylorda Region

Drinking water is a factor that affects the main indicators of sustenance and public health (Bobiniene et al., 2014). Important factors that characterize the sanitary and epidemiological wellbeing include the supply of good-quality drinking water to the population (Wang et al., 2014). It was found that 80% of diseases worldwide are related to the poor quality of drinking water and violation of sanitary and hygienic standards of water supply (Batabyal & Chakraborty, 2015). Five million people die each year because of poor water quality, including 3.2 million children who die of diarrheal diseases (Guarino et al., 2014).

In the 1990s, the western world became aware of the ecological disaster occurring at the fourth largest lake in the world – the Aral Sea. The demise of the Aral Sea has been called one of the twentieth century's worst environmental catastrophes. The drastic desiccation of the Aral Sea led to the intensification of desertification processes in the region and the development of a new desert, the Aralkum, on the dried sea bottom. In the last few decades, the exposed bottom has become the new "hot spot" of dust and salt storms in the region (Indoitu et al., 2015). Up to 700,000 tons of hazardous salt are carried from the bottom of the dried bottom of the Aral Sea annually in a radius of over 1,000 km, more than 500 kg of which deposit in each hectare of soil in the Amu Darya River delta. The Aral Sea crisis created medical, social, economic, and domestic problems, the solution whereof is extremely expensive (White, 2013). The Aralkum is a threat to the normal life of people and nature not only in its direct proximity, but also in other regions.

When studying the environmental objects of the Aral Sea region, a dependence was found between the GI rate and percentage of non-correspondence of the tap water quality to the coli-index standard (Heaney et al., 2012). The supply of tap water to the population in the Aral Sea region (about 0.7% per annum) is lagging behind the pace of settlement development and population growth (White, 2013). An unfavorable trend of deteriorating quality of water in water sources and drinking water by many sanitary, hygienic, and microbiological indicators was discovered in the Aral area of Karakalpakstan. The general percentage of tap water samples in Karakalpakstan that did not meet the standard of bacteriological indicators grew to 14.6% (Omarova et al., 2015).

The state of domestic drinking water supply to the population in the Aral Sea region was assessed as unsatisfactory from the sanitary and hygienic perspective (Anaedi, 2002). This is caused by the low level of tap water provision to the population, increasing mineralization of the main sources of water, deteriorating quality of drinking water, insufficient sanitary, technological, and hygienic effectiveness of water treatment facilities, and unfavorable conditions of public water use (Dzhumagaliyeva et al., 2015).

Central Asian states and the international community are taking measures to solve the problems of environmental disaster in the Aral Sea region (Ragab & Prudhomme, 2002). However, these measures are mostly aimed at managing the consequences of the environmental disaster rather than tackling its cause. The main efforts and means allocated by countries and international humanitarian organizations are used to support the living standard of people (Bernauer & Siegfried, 2012).

The studied districts of the Aral Sea region have not municipal services responsible for land improvement (construction of public bathrooms, dumps). This means that the level of environmental contamination (soil and water) should be monitored more extensively and frequently; it is also necessary to analyze and compare the GI rates in the districts.

Aim of the Study

The aim of this study is to conduct a biological monitoring of the environmental contamination (soil and water) level in the districts of the Aral Sea region under consideration.

Research questions

The overarching research question of this study was as follows: what is the level of environmental CB contamination and GI rate in the environmental disaster area in the Kyzylorda Region?

Methods

The research was done in environmental disaster areas (Aral District, Kazaly District) and environmental crisis areas (Karmakshy District, Zhalagash District, and Shieli District).

Information provided by district sanitary inspection departments regarding the level of environmental biological contamination (soil and water) for 2004-2013 and data from the investigation of soil and water samples that were gathered in the territory of the environmental disaster areas under consideration were studied and generalized.

Soil and water samples were taken from different spots of soil and surface waterbodies in settlements. A total of 350 samples were gathered. The gathering, treatment, preparation for analysis, and investigation of samples for CB was carried out according to methodological recommendations. The sanitary and bacteriological assessment of water was studied by the following indexes: total bacterial count (TBC) is the total count of all microorganisms in 1 cm3 (lm) or 1 g of substrate. TBC gives an idea of the epidemiological situation in the studied districts (Edberg et al., 2000). The assumption was that the more microorganisms are found in the environment, the more probable the contamination with pathogenic microorganisms is. Decimal solutions for sample inoculation on growth media bismuth sulfite agar (BSA), SS agar (Ploskirev agar), Endo agar, with subsequent re-inoculation on Russell agar, and selenite broth were used to detect salmonella and other types of enterobacteriaceae. Smears were prepared from colonies and stained according to Gram's method. Gram-negative bacilli were checked for oxidase activity. This was followed by identification of typical colonies that grew on agar media and the study of their biochemical characteristics (Sokolov et al., 2014).

The areas were ranked in terms of CB contamination level and GI rate in descending order.

Data, Analysis, and Results

The analysis of data from the monitoring of soil CB contamination showed significant contamination of soil. The detection of E.coli in districts ranged from 12.5% (Shieli District) to 33.3% (Aral District). The detection of S.aureus ranged from 9.1% (Karmakshy District) to 20% (Zhalagash District).

E.coli was detected most regularly and at highest percentages (from 17.6% to 25%). S.aureus was common (from 27.3% to 50%). E.coli, which were chosen as the indicator infection agent, were constantly detected in all studied samples across all districts.

The TBC index ranged from 2.1 to 6.7 in all districts with the exception of the Shieli District, where it was the lowest (0.9-3.0).

The results of soil sample investigation for CB are presented in Table 1.

Table 1. Detection of CB in soil samples (summer months)

Districts	Detection of potentially pathogenic bacteria (in %)				
	E.coli	S.aureus	A.niger	Proteus	Klebsiella
Aral	33.3	13.3	26.7	6.7	40.0
Kazaly	31.5	21.1	-	21.1	36.8
Karmakshy	18.1	9.1	18.1	-	36.3
Zhalagash	13.3	20.0	-	-	26.6
Shieli	12.5	15.6	15.6	9.4	31.2

Table 1 shows that the detection of E.coli across districts ranged from 12.5% in the Shieli District to 33.3% in the Aral District. The detection of S.aureus ranged from 9.1% (Karmakshy District) to 20% (Zhalagash District). The detection of E.coli is indicative of fresh soil contamination. Other bacteria were detected irregularly.

The characteristics of the bacterial composition of gathered water samples are presented in Table 2.

Table 2. Detection of CB in water samples (summer months)

Districts	Detection of potentially pathogenic bacteria (in %)				
	E.coli	S.aureus	A.niger	Proteus	Ps.aeruginoza
Aral	25.0	50.0	12.5	-	-
Kazaly	22.2	44.4	-	-	-
Karmakshy	20	40.0	-	-	-
Zhalagash	18.9	27.3	-	9.1	-
Shieli	17.6	29.4	-	11.7	5.9

Table 2 shows that the greatest amount of contaminated samples was found in the Aral District: E.coli – 25%, S.aureus – 50%, A.niger – 12.5%. A smaller number of contaminated samples was found in the Shieli District. However, microorganisms of the Proteus genus (11%) and Ps.aeruginoza (5.9%) were detected in this district. E.coli was detected most regularly and at highest percentages (from 17.6% to 25%). S.aureus was common (from 27.3% to 50%).

Samples gathered during the cold season were also checked for bacteria (Table 3).

Table 3. Detection of CB in water samples (winter months)

Districts	Detection of potentially pathogenic bacteria (in %)				
	E.coli	S.aureus	A.niger	Proteus	Ps.aeruginoza

Aral	18.0	34.2	-	-	-
Kazaly	20.2	21.7	-	-	-
Karmakshy	18.1	25.2	-	-	-
Zhalagash	22.1	16.1	-	-	-
Shieli	13.3	14.3	-	4.7	-

E.coli and S.aureus were also detected regularly in water samples across regions – from 13.3% to 22.2% and from 14.3% to 34.2%, respectively. However, the number of positive findings in wintertime was significantly smaller than in summertime. This is apparently related to the reduced risk of bacterial contamination of water in winter, adsorption of bacteria in suspended soil particles (adsorbents), deposition in silt, absence of the swimming factor, etc.

It is worth noting that most examined soil and water samples contained various microorganisms (two or three species). E.coli, which were chosen as the indicator infection agent, were constantly detected in all studied samples across all districts.

The areas were ranked in terms of the level of CB contamination by the frequency of E.coli detection in samples gathered in the territory (Table 4).

Table 4. Ranking of districts by the level of E.coli soil contamination and GI rate

Districts	Summer months		Winter months		Averaged contamination index (%)	Rank No.	Morbidity rate index (0/0000)	Rank No.
	Contamination index (%)	Rank No.	Contamination index (%)	Rank No.				
Aral	33.3	1	26.7	2	30.0	1	109.1	3
Kazaly	31.5	2	28.3	1	29.9	2	237.5	1
Karmakshy	18.1	3	9.1	4	13.6	3	194.8	2
Zhalagash	13.3	4	7.1	5	10.2	5	99.3	4
Shieli	12.5	5	10.0	3	11.3	4	85.1	5

Table 4 shows that the rankings of districts in terms of soil contamination in summer and winter months were similar, with the exception of the Shieli District (3 and 5). At the same time, the rankings of districts in terms of the averaged contamination index and GI rate were similar, with the exception of the Aral District – rank No. 1 in terms of contamination and rank No. 3 in terms of GI rate.

The rankings of districts were then compared in terms of E.coli waterbody contamination and GI rate (Table 5).

Table 5. Ranking of districts by the level of E.coli water contamination and GI rate

Districts	Summer months		Winter months		Averaged contamination index (%)	Rank No.	Morbidity rate index (0/0000)	Rank No.
	Contamination index (%)	Rank No.	Contamination index (%)	Rank No.				
Aral	25.0	1	18.9	3	21.8	2	109.1	3
Kazaly	22.2	2	22.2	1	22.2	1	237.5	1
Karmakshy	20.0	3	18.1	4	19.0	4	194.8	2
Zhalagash	18.9	4	22.1	2	20.5	3	99.3	4
Shieli	17.6	5	13.3	5	15.5	5	85.1	5

The rankings of districts in terms of E.coli water contamination in summer and winter months were similar in the Kazaly District and Karmakshy District, matched in the Shieli District, and differed significantly in the Aral District (No. 1-3) and Zhalagash District (No. 2-4). However, the comparison of rankings in terms of average contamination and morbidity rate found them to be similar in all the districts, with the exception of the Karmakshy District.

The research found a significant level of environmental contamination with CB, including E.coli.

A link between the level of environmental contamination and the GI rate was traced. However, these indexes weakly correlate with the severity of the environmental disaster in the districts. These data substantiate the need to monitor constantly the level of environmental contamination and the GI rate.

The bacterial composition in the gathered water samples showed that the greatest number of contaminated samples were found in the Aral District: E.coli – 25%, S.aureus – 50%, A.niger – 12.5 %. The smallest number of contaminated water samples was found in the Shieli District.

The analysis of data from soil CB contamination monitoring showed significant contamination: the total microbial count ranged from 2.1 to 6.7. The detection of E.coli ranged from 12.5% (Shieli District) to 33.3% (Aral District). The detection of S.aureus ranged from 9.1% (Karmakshy District) to 20% (Zhalagash District).

Most examined soil and water samples contained various microorganisms (two or three species). E.coli, which were chosen as the indicator infection agent, were constantly detected in all studied samples across all districts.

The rankings of areas by E.coli contamination and GI rate coincide or are very close, but weakly correlate with the severity of the environmental disaster.

Discussion and Conclusion

The research found significant environmental contamination with CB. Biological environmental contamination is uneven across the districts and environmental objects. The analysis of data from soil CB contamination monitoring showed significant contamination: the total microbial count ranged from 2.1 to 6.7. The detection of E.coli ranged from 12.5% (Shieli District) to 33.3% (Aral District). The detection of S.aureus ranged from 9.1% (Karmakshy District) to 20% (Zhalagash District).

The bacterial composition in the gathered water samples showed that the greatest number of contaminated samples were found in the Aral District: E.coli – 25%, S.aureus – 50%, A.niger – 12.5 %. The smallest number of contaminated water samples was found in the Shieli District. However, microorganisms of the Proteus genus (11%) and Ps.aeruginoza (5.9%) were detected in this district. The detection of Proteus microorganisms in water is indicative of the object contamination with decomposing substrates and the sanitary problems of the territory. When Proteus is detected in water, such water should not be used for drinking. Ps.aeroginosa can reproduce in the environment, often in the amelanotic hard-to-detect forms. It is often found in wastewater. Its significance has increased due to the spread of antibiotic-resistant strains and the emergence of a large number of carriers among people.

High GI rates were also found in the most contaminated districts – Aral District, Kazaly District, and Karmakshy District – 109.1, 237.5, and 194.8, respectively. The lowest GI rate was found in the Shieli District (85.1).

The ranking of studied districts by environmental CB contamination and GI rate showed that the rankings either matched or were similar, which is indicative of a close relation between the investigated variables.

The obtained results support the data of cited researchers regarding the role of soil and water in the transmission of GI causative agents and supplement the basic theories of the environmental epidemiology of infectious diseases.

However, these data necessitate doing similar research in all districts and regions of Kazakhstan, with a view to drawing a map of contamination and GI rate. To that end, it is worth considering the following conclusions:

1. The rankings of areas by E.coli contamination and GI rate coincide or are very close, but weakly correlate with the severity of the environmental disaster.

2. Environmental objects (soil and water) in the districts are unevenly contaminated with GI causative agents.

3. Several districts displayed synchronous intensity of contamination and morbidity rate; however, this was not true for all districts, which is probably related to omissions in the registration of patients and indication of causative agents in the environment.

4. Indicators of environmental contamination can serve as an integral biorisk indicator, while GI can be used as indicator diseases in these regions.

Implications and Recommendations

Implications and recommendations for future studies are as follows: Firstly, with a view to preventing the emergence and spread of GI, regional inspections and monitoring services should develop a prospective plan for enhancing the monitoring of biological soil contamination and various water supply sources. Therefore, healthcare agencies should guarantee a comprehensive detection, registration, and recording of patients with GI.

Disclosure statement

No potential conflict of interest was reported by the authors.

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