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RESEARCH ARTICLE

ASSESSMENT OF WATERBORNE PARASITES IN DRINKING WATER SOURCES IN IRAQ

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Abstract

Background and Aim: Waterborne parasites present substantial health hazards, hence requiring extensive research efforts to ascertain their prevalence and spatial dispersion. The objective of this study is to examine the prevalence of Cryptosporidium spp., Entamoeba histolytica, and Giardia lamblia in samples of river and municipal water collected from various geographical areas. The main objective of this study is to evaluate and contrast the occurrence of waterborne parasites in various drinking water sources, thereby offering valuable insights into spatial disparities and facilitating the development of focused strategies for managing water quality.

Materials and Methods: Water samples were obtained from four distinct geographical areas, namely Al-Awja, Amarah, Tikrit, and Sultan Abdullah, which encompass both river and urban water sources. The detection of parasites was carried out utilizing established protocols.

Results: Among the many water samples collected from rivers, it was observed that Al-Awja demonstrated the greatest overall prevalence rate of 53.33%. Notably, the municipal water in Al-Awja and Amarah exhibited considerable rates of 17.77% and 4.44% respectively. The major species observed were Cryptosporidium spp. and Giardia lamblia. There was a positive correlation observed between parasite prevalence and seasons in both river water samples (0.019567) and city water samples (0.023613). The correlation coefficient of 0.987524 indicates that the observed relationship may lack statistical significance between Parasites prevalence and sources of water.

Conclusion: Waterborne parasites are common, highlighting the need for tailored water quality control. The increased frequency in certain locations emphasises the need for public health surveillance and informed responses. This research advances our understanding of waterborne parasite spatial dynamics, guiding water safety and community health measures.

Introduction:-

Waterborne parasites are tiny microorganisms that flourish in water sources and have the potential to induce illnesses in humans by ingestion or direct contact. The presence of these parasites presents a substantial risk to the well-being of the general population, as the contamination of water sources can result in extensive occurrences of

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waterborne illnesses. Regions with insufficient sanitation and water treatment infrastructure see a notably profound effect on public health [1, 2].

Infections can give rise to a variety of symptoms, spanning from gastrointestinal discomfort to more serious manifestations, so posing a threat to populations that are particularly susceptible. The implementation of efficient water treatment methods, enhanced sanitation practices, and the dissemination of public knowledge are essential factors in reducing the potential harm caused by waterborne parasites and ensuring the well-being of the community [3, 4].

Prevalence of parasites in drinking water sources:

The presence of many waterborne parasites in drinking water is a common occurrence, with notable examples including Giardia lamblia, Cryptosporidium, and Entamoeba histolytica. Giardia lamblia, a unicellular organism possessing flagella, is responsible for the occurrence of giardiasis, a gastrointestinal infection characterized by symptoms such as diarrhea and abdominal cramps. Cryptosporidium, an infinitesimal parasite, is responsible for the development of cryptosporidiosis, a condition characterized by symptoms such as diarrhea and nausea [5].

The pathogenic amoeba Entamoeba histolytica is responsible for the development of amoebiasis, a condition characterized by intestinal inflammation and the manifestation of symptoms such as abdominal pain and the presence of blood in the stools. These parasitic organisms have the potential to contaminate water sources by means of fecal contamination, hence presenting a potential hazard to the well-being of the general population [6].

The worldwide viewpoint about waterborne parasites highlights the widespread difficulties and health hazards linked to polluted water sources. Developing regions frequently encounter increased risks as a result of inadequate sanitary infrastructure and restricted availability of potable water. Waterborne infections can exhibit a high prevalence in certain regions, leading to a disproportionate impact on vulnerable groups. Nevertheless, the longevity of these parasites remains a concern even in affluent nations, where failures in water treatment or the influence of environmental factors might contribute to their survival [4,7].

Standards for drinking water quality in Iraq:

Iraq has implemented water quality standards and regulations in order to effectively manage issues pertaining to water contamination and guarantee the safety of its water supply. It is probable that the nation depends on a blend of domestic and global directives in order to establish these criteria [8]. It is probable that governmental entities such as the Iraqi Ministry of Health and the Ministry of Water Resources are responsible for the supervision and execution of water quality laws. The aforementioned standards would encompass various aspects including microbiological contamination, chemical contaminants, and physical attributes in order to guarantee the safety and suitability of drinking water [9].

The examination of alterations in the occurrence and classifications of waterborne parasites over a period of time is a complex undertaking influenced by multiple factors. Epidemiological trends exhibit variations that are impacted by factors such as population increase, urbanization, and climate shifts [10, 11]. The accuracy of reported cases is influenced by advancements in detecting methods. Changes in the environment and the ability of parasites to adapt to novel situations are key factors that contribute to fluctuations in the diversity and abundance of parasites. Comprehending these alterations is crucial for the implementation of public health measures [12].

Factors affecting incidence and distribution of waterborne parasites:

The incidence of parasites is influenced by a multifaceted interaction of environmental, socio-economic, and biological factors. Environmental factors encompass several elements such as the accessibility and caliber of water supplies, temperature, and climatic conditions, which significantly influence the proliferation of parasites, as they tend to flourish in particular ecological habitats. Socio-economic factors, including but not limited to the availability of clean water, sanitation facilities, and healthcare infrastructure, exert a significant influence [13, 14].

The transmission of parasites is facilitated by substandard sanitation and insufficient adherence to hygiene protocols. Biological considerations encompass several aspects such as the immune response of the host population, genetic predisposition, and behavioral patterns. The spread of parasites can also be influenced by globalization and travel [15, 16].

The public health implications of waterborne parasites in Iraq are a matter of considerable concern, influenced by a multitude of variables. The lack of adequate access to clean water and sanitary facilities, exacerbated by instances of violence and political instability, has led to an increased susceptibility to waterborne illnesses [17, 18].

Socioeconomic Implications of Water borne parasites:

The existence of waterborne parasites has substantial socioeconomic implications and exerts a huge healthcare burden on populations who are impacted. In areas where there is a lack of sufficient water and sanitation facilities, the high occurrence of waterborne diseases presents a dual issue [19, 20].

To begin with, it is important to admit that the economic impact of illnesses is significant. This is mostly due to the enormous productivity losses incurred as a result of missed workdays, the expenses associated with treatment, and in certain cases, the potential for long-term health complications [21, 22]. Families may encounter financial burden as a result of medical expenditures, particularly in regions characterized by limited access to healthcare resources [23].

Furthermore, the healthcare burden is exacerbated as there is an increase in the demand for medical services during epidemics. Healthcare systems that are overwhelmed may face challenges in delivering treatment that is both timely and effective, hence worsening the overall impact on public health [24, 25].

Health Implications of Water borne parasites:

Waterborne parasites present a notable risk to susceptible demographics, such as children, the elderly, and persons with compromised immune systems. Certain demographic groups are at a higher risk of experiencing catastrophic health outcomes due to many circumstances, including inadequate immune responses, pre-existing health issues, and limited access to proper healthcare services [26, 27]. In the context of pediatric health, infections have the potential to result in growth retardation, malnourishment, and developmental impairments [28, 29]. The aged population frequently has reduced immune function, rendering them more susceptible to severe and protracted infections [23].

Individuals who have compromised immune systems, such as those diagnosed with HIV/AIDS or receiving immunosuppressive therapies, face an increased susceptibility to experiencing severe and perhaps fatal problems resulting from parasite infections transmitted through water. In order to cater to the requirements of these susceptible populations, it is imperative to implement focused public health interventions. These interventions should encompass enhancements in water and sanitation infrastructure, programs aimed at health education, and the provision of easily available healthcare facilities [30, 31].

Technologies for water treatment in the context of parasite removal:

In the realm of water treatment, the utilization of innovative technology assumes a pivotal role in the efficient eradication of parasites and the augmentation of water quality. An exemplary progress is the utilization of sophisticated filtration systems. Membrane filtration methods, such as ultrafiltration and nanofiltration, have demonstrated efficacy in the removal of parasites and other microbes from water, serving as a robust physical barrier to impede their passage [32, 33].

UV-C irradiation is a further novel approach. Ultraviolet (UV) radiation has the ability to interfere with the genetic material of parasites, hence impeding their ability to replicate and leaving them biologically inert [34, 35]. The application of UV-C treatment has demonstrated notable efficacy in combating waterborne parasites, hence presenting a viable disinfection method that is devoid of chemical agents [36].

Ozonation is a nascent technological approach in which ozone gas is put into water for the purpose of disinfection and elimination of parasites. Ozone is a highly potent oxidizing agent that efficiently neutralizes a diverse array of waterborne pathogens [37, 38].

Furthermore, the progress made in sensor technology and real-time monitoring systems has facilitated the rapid identification of water quality concerns, so enabling timely actions. These technologies play a significant role in improving the efficiency and reliability of water treatment procedures, thereby mitigating the potential risks associated with waterborne parasite contamination and ultimately improving public health outcomes [39, 40].

The objective of this study is to conduct a complete assessment of the occurrence and frequency of waterborne parasites in two significant water sources, namely the Tigris River and municipal water, across four specific localities. The selected locations offer a comprehensive representation of the region, while the study has a duration of six months in order to examine the impact of several seasons on water quality. The research endeavors to provide insights into probable locations of contamination within the water distribution network by examining both natural water bodies and treated municipal water.

Materials and Methods:-

A cross-sectional study was undertaken to evaluate the incidence of waterborne parasites in drinking water sources across several locations in Iraq. The investigation was conducted over a period of 6 months from January 2023 till the end of June 2023 in order to account for any potential seasonal fluctuations. We collected the water samples three times in winter (January), spring (April) and in the end of June (summer) to assess the waterborne parasites in different seasons.

In order to achieve a sample that is both representative and diverse, a cross-sectional methodology was employed, encompassing a range of geographical contexts such as urban, suburban, and rural regions. The sample procedure entailed the random selection of drinking water sources from various strata, including Tigris River, and municipal water supplies. To address potential regional variations in water quality and parasite prevalence, stratification was employed based on geographical regions. 120 water samples were collected in each assessment, 60 sample from locations around Tigris River including 2 villages (Al-awja, Sultan Abdullah) and two cities (Amarah ,Tikrit) and 60 sample was collected from municipal water supplies in the same villages and cities.

The samples that were chosen for analysis were obtained by field personnel who had received specialized training. These individuals used containers that had been sterilized to collect the samples. Furthermore, the transportation and storage of the samples followed established protocols in order to ensure that the integrity of the samples was maintained. Samples were maintained at 4°C until laboratory analysis.

Upon the receipt of the samples at the laboratory, immediate processing was initiated by employing sedimentation and centrifugation procedures to concentrate any potential parasite material. A direct wet mount was created by applying a tiny amount of the concentrated material onto a microscope slide and then covering it with a coverslip. This allowed for the initial detection of any mobile parasites.

Multiple concentration procedures, such as formalin-ether sedimentation and centrifugal flotation, were utilized in order to augment the sensitivity of detection. Systematic use of staining treatments, such as iodine and modified acid-fast stains, was undertaken to enhance the visibility of parasitic formations and enable precise identification. The microscopic examination was carried out at various magnifications, meticulously examining the slides in order to identify specific morphological traits.

The identification endeavors mostly concentrated on prevalent waterborne parasites, such as Giardia lamblia, Cryptosporidium spp., Entamoeba histolytica.

After the data collection process is over, the subsequent crucial stage entails the analysis of the obtained results in order to extract significant insights and formulate conclusions. Commence the process by arranging the data in a methodical fashion, guaranteeing that it is suitably annotated and classified. The Statistical Package for the Social Sciences (SPSS) version 25.0 used for analysis of data obtained. SPSS is a robust instrument that effectively supports the statistical analysis of data, it provides a user-friendly graphical interface that facilitates data processing, descriptive statistical analysis, and advanced statistical procedures.

Results:-

Assessment in winter for the water borne parasites in river samples:

Table 1 show that, in the river samples in winter, Cryptosporidium spp. (4), Entamoeba histolytica (2), and Giardia lamblia (1), were found in Al-Awja with the highest count of total parasites (7). The four positive parasites in Amarah include Cryptosporidium spp. (2), Entamoeba histolytica (1), and Giardia lamblia (1). The lowest overall positive parasite results are 2 in Tikrit, mostly Cryptosporidium spp. Sultan Abdullah had 5 positive parasite results, including Cryptosporidium spp. (3), Entamoeba histolytica (1), and Giardia lamblia (1).

Table 1:- Water borne parasites in river samples during winter.

	Positive parasite	Giardia lamblia	Entamoeba histolytica	Cryptosporidium spp.
Al- Awja	7	1	2	4
Amarah	4	1	1	2
Tikrit	2	0	0	2
Sultan Abdullah	5	1	1	3
	18	3	4	11

Assessment in winter for the water borne parasites in municipal water samples:
Al-Awja exhibits two cases of Cryptosporidium spp. and one instance of Giardia lamblia. In the region of Amarah, a single instance of Cryptosporidium spp. has been observed, leading to a solitary identification of a positive parasite presence.

Within the geographical region of Tikrit, a single instance of Giardia lamblia has been identified. In the region of Sultan Abdullah, while Cryptosporidium spp. and Entamoeba histolytica are not detected, there is a single instance of Giardia lamblia, as presented in table 2.

Table 2:- Water borne parasites in municipal water samples during winter.

	Positive parasite	Giardia lamblia	Entamoeba histolytica	Cryptosporidium spp.
Al- Awja	3	1	0	2
Amarah	1	0	0	1
Tikrit	1	0	0	1
Sultan Abdullah	1	0	0	0
	6	1	0	5

Assessment in spring for the water borne parasites in river samples:
Assessment of parasites in river samples taken in the spring reveals that: Al-Awja has the highest incidence of parasites, with three instances of Cryptosporidium spp., Entamoeba histolytica, and Giardia lamblia, respectively.

Two cases of Cryptosporidium spp., one case of Entamoeba histolytica, and three cases of Giardia lamblia make up the six positive parasite results in Amarah.

A total of four positive parasite results were recorded in Tikrit, with two cases of Cryptosporidium spp. and one case of Giardia lamblia. Sultan Abdullah has a total of seven positive parasite findings: three cases of Cryptosporidium spp. and two cases of Giardia lamblia, and two cases of Entamoeba histolytica, as illustrated in table 3.

Table 3:- Water borne parasites in river samples during spring.

	Positive parasite	Giardia lamblia	Entamoeba histolytica	Cryptosporidium spp.
Al- Awja	8	3	2	3
Amarah	6	3	1	2
Tikrit	4	2	0	2
Sultan Abdullah	7	2	2	3
	25	10	5	10

Assessment in spring for the water borne parasites in municipal water samples:
During the assessment of waterborne parasites in municipal water samples in the spring season, varied levels of parasite occurrences were identified as table 4 represents. A total of three positive parasite results were observed in Al-Awja, with the presence of Cryptosporidium spp. and Giardia lamblia. Sultan Abdullah presented three instances of positive parasite detection, namely including Cryptosporidium spp., Entamoeba histolytica, and Giardia lamblia. In contrast, the regions of Amarah and Tikrit did not exhibit any instances of the designated parasites.

Table 4:- Water borne parasites in municipal water samples during spring.

	Positive parasite	Giardia lamblia	Entamoeba histolytica	Cryptosporidium spp.
Al- Awja	3	1	0	2
Amarah	0	0	0	0
Tikrit	0	0	0	0
Sultan Abdullah	3	1	1	1
	6	2	1	3

Assessment in summer for the water borne parasites in river samples:

Waterborne parasites in summer river water samples vary by location as elucidated in table 5. Two Cryptosporidium spp., four Entamoeba histolytica, and three Giardia lamblia were found in Al-Awja. Amarah had 7 parasites: 1 Cryptosporidium spp., 2 Entamoeba histolytica, and 4 Giardia lamblia. There were 4 positive parasite findings in Tikrit: no Cryptosporidium spp., 1 Entamoeba histolytica, and 3 Giardia lamblia. Sultan Abdullah had 8 positive parasites: 1 Cryptosporidium spp., 3 Entamoeba histolytica, and 4 Giardia lamblia.

Table 5:- Water borne parasites in river water samples during summer.

	Positive parasite	Giardia lamblia	Entamoeba histolytica	Cryptosporidium spp.
Al- Awja	9	3	4	2
Amarah	7	4	2	1
Tikrit	4	3	1	0
Sultan Abdullah	8	4	3	1
	28	14	10	4

Assessment in summer for the water borne parasites in municipal water samples:

Two instances of parasitic infection were documented in Al-Awja, with both cases being attributable to the presence of Giardia lamblia as demonstrated in table 6.

During the summer season, both Amarah and Tikrit reported a single positive parasite discovery. The occurrence of Entamoeba histolytica in Amarah and the identification of Giardia lamblia in Tikrit were the contributing factors for the respective positive findings in these locations. Sultan Abdullah documented the identification of two parasitic organisms, specifically the detection of both Entamoeba histolytica and Giardia lamblia.

Table 6:- Water borne parasites in municipal water samples during summer.

	Positive parasite	Giardia lamblia	Entamoeba histolytica	Cryptosporidium spp.
Al- Awja	2	2	0	0
Amarah	1	0	1	0
Tikrit	1	0	1	0
Sultan Abdullah	2	1	1	0
	6	3	3	0

Prevalence of parasites in water samples and seasons correlation:

Positive parasite counts in river water samples were recorded in winter, spring, and summer as table 7 showing. In winter, Cryptosporidium spp. 11, Entamoeba histolytica 4, and Giardia lamblia 3 were common.

Spring prevalence was 10 Cryptosporidium spp., 5 Entamoeba histolytica, and 10 Giardia lamblia. Summer saw 4 Cryptosporidium spp., 10 Entamoeba histolytica, and 14 Giardia lamblia. Parasite prevalence varied seasonally in municipal water samples. Cryptosporidium spp. 5, Entamoeba histolytica 0, and Giardia lamblia 1 were prevalent in winter. Spring prevalence was 3 Cryptosporidium spp., 1 Entamoeba histolytica, and 2 Giardia lamblia. The summer prevalence of Cryptosporidium spp. was 0, Entamoeba histolytica 3, and Giardia lamblia 6. Parasite prevalence and seasons were positively correlated for river water samples (0.019567) and municipal water samples (0.023613).

Table 7:- Parities prevalence during different seasons.

	Giardia lamblia	Entamoeba histolytica	Cryptosporidium spp.	P value
River water samples				
Winter	3	4	11	0.019567
Spring	10	5	10	
summer	14	10	4	
Municipal water samples				
Winter	1	0	5	0.023613
Spring	2	1	3	
Summer	6	3	0	

Parasites prevalence and sources of water correlation:
The recorded results for Cryptosporidium spp., Entamoeba histolytica, and Giardia lamblia in rivers were 25, 19, and 27, respectivelyas table 8 and figure 1 elucidate.. The observed counts in municipal water samples were 5 for Cryptosporidium spp., 4 for Entamoeba histolytica, and 6 for Giardia lamblia, indicating a notable numerical association. The correlation coefficient of 0.987524 suggests that the observed link may not possess statistical significance.

Table 8:- Correlation between parasites and source of sample:

	Giardia lamblia	Entamoeba histolytica	Cryptosporidium spp.	P Value
River	27	19	25	0.987524
Municipal	6	4	5	

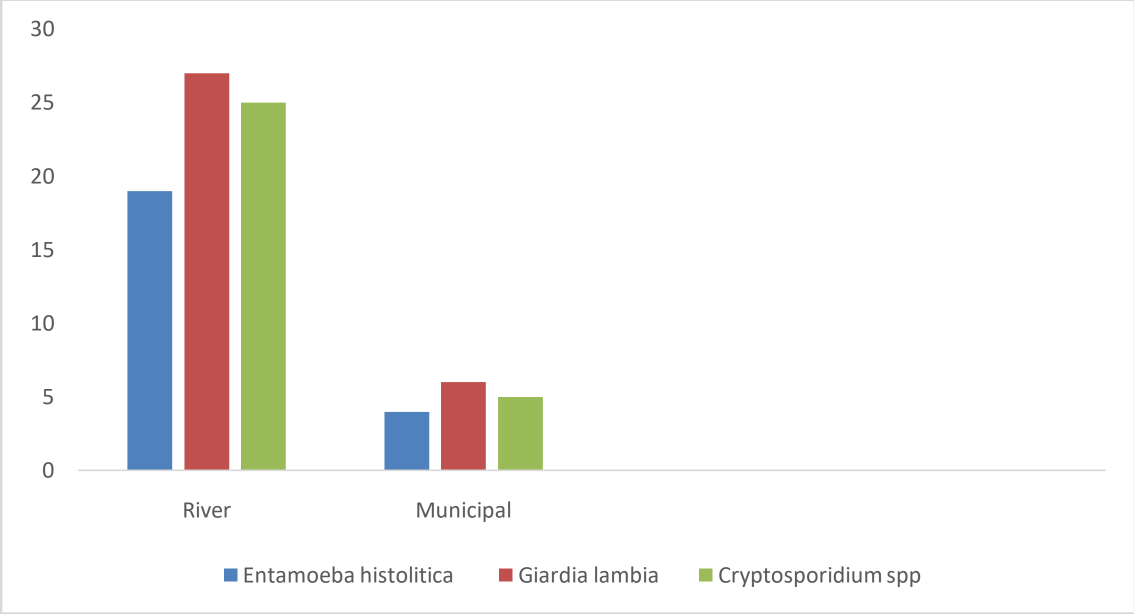

Figure 1:- Parasites prevalence difference in both sources of water.

Distribution of parasites prevalence in river water according to regions of sampling:
Table 9 and figure 2 demonstrate that, Al-Awja has 53.33% parasites, with Cryptosporidium spp. at 20%, Entamoeba histolytica at 17.77%, and Giardia lamblia at 15.55% . Amarah has 37.77% prevalence, Cryptosporidium spp. 11.11%, Entamoeba histolytica 8.88%, and Giardia lamblia 17.77% .

With Cryptosporidium spp. at 8.88%, Entamoeba histolytica at 2.22%, and Giardia lamblia at 11.11%, Tikrit has 22.22% prevalence.At 44.44%, Sultan Abdullah has Cryptosporidium spp. at 15.55, Entamoeba histolytica at 13.33, and Giardia lamblia at 15.55 .

All samples show 13.88% Cryptosporidium spp., 10.55% Entamoeba histolytica, and 15% Giardia lamblia prevalence across all regions .Al-awja had the most parasites and Tikrit the lowest, Giardia lamblia is most prevalent parasite.

Table 9:- Prevalence of parasites in river water according to regions of sampling:

	Giardia lamblia		Entamoeba histolytica		Cryptosporidium spp.		Total prevalence of parasites	
	No.	%	No.	%	No.	%	No.	%
Al- Awja	7	15.55%	8	17.77%	9	20%	24	53.33%
Amarah	8	17.77%	4	8.88%	5	11.11%	17	37.77%
Tikrit	5	11.11%	1	2.22%	4	8.88%	10	22.22
Sultan Abdullah	7	15.55%	6	13.33%	7	15.55%	20	44.44%
180	27	15%	19	10.55%	25	13.88%		

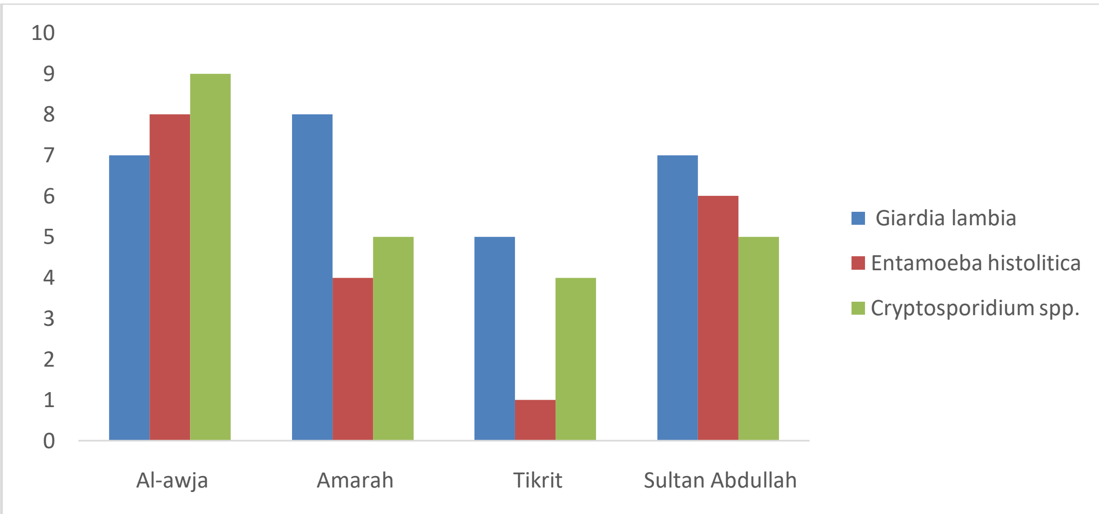

Figure 2:- Parasites prevalence in river water at different regions of sampling.

Distribution of parasites prevalence in municipal water according to regions of sampling:

Table 10 demonstrates that, the parasite prevalence in Al-Awja is 17.77%, with Cryptosporidium spp. and Giardia lamblia each contributing 8.88%.

Amarah has 4.44% prevalence, with Cryptosporidium spp. and Giardia lamblia each having one incidence.

Tikrit has 4.44% prevalence, with Cryptosporidium spp. and Giardia lamblia contributing 2.22% each.

Sultan Abdullah has 11.11% prevalence, with Cryptosporidium spp. at 2.22% and Entamoeba histolytica and Giardia lamblia at 4.44%.

Cryptosporidium spp., Entamoeba histolytica, and Giardia lamblia have prevalence rates of 3.88%, 2.22%, and 3.33%, respectively, in all locations.The most common parasite is Cryptosporidium. Tikrit and Amarah have the lowest parasite prevalence, whereas Al-awja has the highest.

Table 10:- Prevalence of parasites in municipal water according to regions of sampling.

	Giardia lamblia		Entamoeba histolytica		Cryptosporidium spp.		Total prevalence parasites	
	No.	%	No.	%	No.	%	No.	%
Al- Awja	4	8.88%	0	0%	4	8.88%	8	17.77%
Amarah	0	0%	1	2.22%	1	2.22%	2	4.44%
Tikrit	0	0%	1	2.22%	1	2.22%	2	4.44%
Sultan Abdullah	2	4.44%	2	4.44%	1	2.22%	5	11.11%
180	6	3.33%	4	2.22%	7	3.88%		

Discussion:-

This study explores the intricate findings pertaining to the evaluation of waterborne parasites in drinking water sources in Iraq. The study spans a duration of six months, deliberately selected to encompass a wide range of seasonal variations. It specifically examines the Tigris River and municipal water in four unique geographical areas. This section examines the frequency and categories of waterborne parasites detected in the study, emphasizing any differences noted in relation to seasons and geographical areas.

Water acts as a main channel for the spread of Giardia cysts and Cryptosporidium oocysts, playing a crucial role in the transmission of these parasites [41]. Multiple research and reports emphasize the substantial influence of water in the dissemination of several parasites, including Giardia lamblia and Entamoeba histolytica [42]. The complex interaction between these aquatic infections and their environmental pathways emphasizes the crucial significance of water in the wider scope of parasite transmission.

Cryptosporidiosis and giardiasis are the main waterborne diseases that are commonly reported in Iran, particularly during outbreaks that are associated with contaminated water sources [43]. This is consistent with our study's focus on the widespread occurrence of these disease-causing parasites that can be transmitted between animals and humans. It also underscores the worldwide importance of managing water quality.

Our analysis has revealed a significant presence of waterborne parasites. Specifically, we found a prevalence rate of 13.88% for Cryptosporidium spp., 10.55% for Entamoeba histolytica, and 15% for Giardia lamblia. Our findings align with a study carried out in Saudi Arabia, which revealed that Cryptosporidium was present in 51% and 25% of tap water samples in Jeddah and Makkah, respectively. Similarly, the presence of Giardia lamblia was detected in 0.62% and 2.4% of tap water samples in the exact same areas [44], highlighting the global significance of our findings.

In addition, our findings align with a study carried out in Nahia and Saft Al-Laban, Giza governorate, Egypt, which documented a prevalence rate of 11.1% for Cryptosporidium and 5.6% for Entamoeba [45].

In our investigation, we found a clear seasonal pattern, with a strong relationship between the presence of parasites and specific seasons in both river and city water samples (correlation coefficients: 0.019567 for river samples and 0.023613 for municipal water samples). The observed correlation led to a further in-depth investigation of the factors that affect the abundance of parasites during various seasons.

A study carried out in Baghdad, Iraq, emphasized the influence of seasonal variations on the contamination of river water. More precisely, an increase in the quantity of cryptosporidium oocysts was noticed specifically when it rained, especially during the time when cows and sheep give birth. Simultaneously, rainwater runoff occurred, carrying cattle excrement with oocysts into the river water [46].

A separate study highlighted the resilience of the majority of amoebae that live freely in their natural environment to traditional disinfection methods commonly used in the treatment of drinking water. Significantly, free-living amoebae exhibited higher prevalence during warmer months as a result of their capacity to withstand harsh temperatures [47].

A 2019 study indicated that there may be an increase in human exposure to Cryptosporidium through untreated surface waters during colder months, which is caused by lower air and water temperatures [48]. These results are Similar to a study conducted in Riyadh, Saudi Arabia in 2017, that have shown a greater occurrence of giardia and entamoeba infections during the spring and summer months (March–August) as opposed to the autumn and winter months (September–Februar) [49].

An investigation in Iraq revealed that there were significant increases in the frequencies of Giardia and E. histolytica infections throughout the month of June, reaching a peak of 20%. This coincided with the higher temperatures experienced during the summer season. [50].

Additionally, the monthly prevalence of intestinal parasite infections in the Qassim region of Saudi Arabia exhibited the highest rates of infection in June and August (summer) and the lowest rates in December and January (winter) [51].

Our study found that Al-Awja, which is classified as a rural area, had the highest occurrence of parasites in both river and municipal samples. Sultan Abdullah, another rural location, had a similar frequency of parasites, closely following Al-Awja. In contrast, Tikrit and Amarah, which are both metropolitan regions, exhibited a reduced occurrence of waterborne parasites in both river and municipal samples.

An earlier study revealed a significant reduction in the occurrence of parasites in samples collected from municipal sources as compared to samples collected from rivers. The decrease in water contamination was ascribed to the implementation of water treatment procedures prior to the water entering the municipal distribution system, which is consistent with the results of a research conducted in Baghdad, Iraq [46].

In line with these findings, a further study reported a greater occurrence of parasitic illnesses in rural regions (9.8%) as opposed to urban regions (6.2%) [52]. Moreover, inquiries have shown that untreated water obtained from open wells and streams often contains a significant number of Entamoeba species, Giardia lamblia, and other waterborne parasites. The increased vulnerability of rural people to many aquatic infections is emphasized by this heightened risk [53].

Comparable patterns were detected in other geographical areas. Waterborne parasite infections were found to be more prevalent in rural homes than in urban ones in Pakistan [54]. Similarly, in India, there was a strong correlation between impoverished economic situations and the intake of untreated drinking water with the occurrence of Entamoeba spp. in rural regions [55]. These combined results highlight the differences in the occurrence of parasites between rural and urban settings.

Conclusion:-

The analysis of waterborne parasites in river and municipal water samples from different locales has unveiled differing rates of occurrence. The significance of the spatial distribution of Cryptosporidium spp., Entamoeba histolytica, and Giardia lamblia emphasises the necessity for customised tactics in managing water quality. Specific geographical areas demonstrated an increased incidence of parasites, particularly in the context of municipal water sources. This underscores the importance of ongoing surveillance and focused interventions. The aforementioned findings provide valuable contributions to the understanding of the intricate dynamics of waterborne parasites, hence offering guidance for making well-informed decisions on public health interventions. The observed discrepancies necessitate additional inquiry into the precise aspects that influence the incidence of parasites, in order to foster a full comprehension of water safety standards that are successful.

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