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Review Article

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Pathogenic organisms in sewage: a review

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Abstract

Pathogens are a general health hazard with risks in nearly all parts of the world. Waterborne pathogens may occur in all water types and are particularly rampant in areas where there are large amounts of untreated wastewater. Wastewater contains waste products. These waste products are most often liquid, or solids and they can be biological, chemical, or radioactive. In addition to having adverse health implications, wastewater contamination can also have natural and ecological effects. These may include the degradation of ecosystems such as a decrease in important aquatic plants that help preserve the condition of waterways or biodiversity loss such as loss of aquatic life like fish and crustaceans that are an important part of both animal and human diet. Wastewater is becoming increasingly important to society, not only because it can be used to augment dwindling freshwater supplies, but also because it can be used for energy production and the recovery of nutrients and other resources. To realize these benefits, wastewater needs to be treated sufficiently to ensure that it is affordable while still protecting public health. This is an important consideration because without public confidence in recycled water it will not be accepted, but at the same time if it is too expensive then consumers will use the cheapest water available, which is often surface water or groundwater. Many microorganisms (viruses, bacteria, protozoans) associate with particles, which can allow them to survive disinfection processes and cause a health hazard. Improved understanding of this association will enable the development of cost-effective treatment, which will become increasingly important as indirect and direct potable reuse of wastewater becomes more widespread in both developed and developing countries. This review provides an overview of wastewater and organisms living in it, the pathogens in wastewater.

Keywords Pathogens, Reuse, Treatment, Wastewater, Sewage

Introduction

Water is the basic component for all living organisms, as its existence is linked to the presence of water abundance. Due to the increase in its use and ease of access by humans, it has become more susceptible to pollution through human activities, which causes a change in its natural properties, as water environments, especially rivers, are used as drainage sites. Waste is generated from various activities, whether human, industrial, or agricultural (Ambasht, 2015). Domestic wastewater that is directly thrown into rivers is considered one of the main problems that cause pollution in all kinds of water (surface and ground) in many countries of the world as a result of being untreated. Or partially treated, and one of these countries is Iraq, due to the lack or inefficiency of the treatment plants in it (Apegebe, 2013).

The dumping of sewage wastewater into river water has a significant impact on it because it works to change the physical and chemical parameters of water and this hurts aquatic organisms, starting with products to the top of the human food chain. Most of the fields of modern research (Mishra, 2012). Wastewater contains a large variety of microorganisms, some of which cause several serious diseases to humans, animals, and plants. Contamination by pathogenic microorganisms is one of the important factors transmitted through water, which results from water pollution. With a range of microorganisms such as bacteria, parasites, viruses, and fungi, waterborne pathogens are a global problem and studies indicate that more than two million deaths occur annually due to the use of unsafe drinking water in some rural areas of third world countries, the majority of which are among children under the age of five (Cyprowski et al., 2018).

Wastewater and its components

It can be defined as the water resulting from various domestic uses, which is mixed with industrial or agricultural wastewater (Al-Safadi and Al-Dhaher 2008). Wastewater is one of the most important risks facing public health, as it is dumped in to the water without treatment or partially treated, especially in developing countries, causing increased water pollution and loss of biodiversity in the water body, as well as the consumption of these wastes by aquatic organisms and their entry into the food chain. Many health problems. The effects of wastewater, especially the completely untreated, on the aquatic environment vary greatly on the quality and concentration of the pollutants it contains (Metcalf and Eddy, 2003). Wastewater contains a very large percentage of water, amounting to about 99.9%. As for the rest of the components, they are pollutants that include suspended solids, self-organic compounds, inorganic solids, nutrients, and minerals, in addition to containing some pathogenic microorganisms (Templeton & Butler, 2011). Industrial wastewater may mix in the sewage of some large cities, making a rise in toxic pollutants such as heavy metals. Pollutants such as asbestos, cyanide, motor oils, grease, hydrocarbons, acids, and some organic wastes reach the sewage network through mineral drifts that carry with them construction wastes, animal waste, salt drifts from roads, and transportation emissions by rainwater, as these drifts are worse than household waste. Among the other components of sewage water in detergents, which cause an increase in the concentration of PO₄ in the water, as well as being foaming on the upper part of the water hinders the gas exchange process (Al-Saadi, 2006). The chemicals that act as hormones or that activate their action are one of the components contained in sewage water, which come from human and veterinary archaeology, hospital waste, and pesticides that cause various cancerous occurrences (WHO, 2006). In general, the main components of wastewater. It was divided into the following four groups (Templeton and Butler 2011).

- 1- feces and other body waste.
- 2- Food waste
- 3- Cellulosic paper materials
- 4- Solid inorganic materials that include surface sediments, soil particles, salts, and minerals

Pathogens in wastewater

Bacteria

Bacteria constitute a group of single-celled prokaryotic organisms, small in size and simple in structure, with several shapes, including spherical, rod, spiral, and others (Todar, 2013). There are several kinds of bacteria distributed in nature and closely related to humans. Some of them are useful and some are harmful to the environment in which humans live, including air pollution, water pollution, soil pollution, and food pollution, and they pose a great danger to human health. There are a large number of bacteria in sewage water. Various bacteria and even bacteria that cause human diseases can be spread through water pollution resulting from the discharge of

wastewater, which poses risks to human health and environmental security. Bacteria are a diverse group of organisms that differ in shape and size, environment, and metabolism. Some different criteria are used to classify bacteria based on differences in shape, metabolism, cell walls, and genes (Dusenbery, 2009). Bacteria are composed of cell walls and membrane, DNA, ribosomes free of chloroplasts, and cellular organelles, either positive or negative for Gram stain, they are motile or non-motile. Most types of bacteria live as trophic or parasitic on other organisms.

Typical bacteria in wastewater

Bacteria are also classified by the roles they play in different situations as in Table 1.

Table 1. Shows the groups of bacteria that are found in wastewater

Typical groups	Examples
Acetogenic bacteria	Acetobacter, Syntrobacter, and Syntrophomonas
Coliforms	Escherichia, Citrobacter, Enterobacter, Hafnia
Cyanobacteria	Anabaena, Chlorella, Euglena, and Oscillatoria
Denitrifying bacteria	Alcaligenes, Bacillus, and Pseudomonas
Fecal coliforms	Escherichia
Fermentative bacteria	Bacteroides, Bifidobacteria, Clostridium, Escherichia, Lactobacillus, and Proteus
Floc-forming bacteria	Achromobacter, Aerobacter, Citromonas, Flavobacterium, Pseudomonas, and Zoogloea
Gliding bacteria	Beggiatoa, Flexibacter, and Thiothrix
Gram-negative aerobic cocci and rods	Beggiatoa, Flexibacter, and Thiothrix Acetobacter, Acinetobacter, Alcaligenes, Nitrobacter, Nitrosomonas, Pseudomonas, and Zoogloea
Gram-negative facultative anaerobic rods	Bacteroides, Bifidobacteria, and Clostridium
Methane-forming	Methanobacterium, Methanococcus, Methanomonas, and Methanosarcinia
Nitrifying bacteria	Nitrosomonas, Nitrospira, Nitrobacter, and Nitrospira
Pathogenic bacteria	Campylobacter jejuni, and Leptospira interrogans
Poly-P bacteria	Acinetobacter, Aerobacter, Beggiatoa, Enterobacter, Klebsiella, and Proteobacter
Saprophytic bacteria	Achromobacter, Alcaligenes, Bacillus, Flavobacterium, Micrococcus, and Pseudomonas
Sulfur-reducing bacteria	Desulfovibrio and Desulfotomaculum

Pathogenic bacteria and their characteristics

Pathogenic bacteria are microbes that can make living organisms be patient and are one of the major public health threats in world. Pathogenic bacteria are capable of infecting and causing diseases of world-level importance, such as pneumonia, typhoid fever, syphilis, leprosy, and foodborne diseases (Chan et al., 2013). Wastewater contains millions of bacteria/ml and is a source of different pathogenic bacteria *Escherichia coli*, *Clostridium perfringens*, *Mycobacterium tuberculosis*, *Legionella pneumophila*, *P. aeruginosa*, *S. flexneri*, *Salmonella enterica*, *Vibrio cholera*. Sanitation in Table 2. (Cai and Zhang, 2013).

Table 2. Commonly pathogenic bacteria in wastewater

Bacterium/Bacteria	Disease
<i>Actinomyces israelii</i>	Actinomycosis
<i>Bacillus anthracis</i>	Anthrax
<i>Brucella</i> spp	Brucellosis (Malta fever)
<i>Campylobacter jejuni</i>	Gastroenteritis
<i>Clostridium perfringens</i>	Gangrene (gas gangrene)
<i>Clostridium tetani</i>	Tetanus.
<i>Clostridium</i> spp	Gangrene gas
Enteroinvasive <i>Escherichia coli</i>	Gastroenteritis
Enteropathogenic <i>Escherichia coli</i>	Gastroenteritis
Enterotoxigenic <i>Escherichia coli</i>	Gastroenteritis
Enterohemorrhagic <i>Escherichia coli</i> O157:	Gastroenteritis and hemolytic uremic
H7	Syndrome
<i>Francisella tularensis</i>	Tularemia
<i>Leptospira interrogans</i>	Leptospirosis
<i>Mycobacterium tuberculosis</i>	Tuberculosis
<i>Nocardia</i> spp	Nocardiosis
<i>Salmonella paratyphi</i>	Paratyphoid fever
<i>Salmonella</i> spp.	Salmonellosis
<i>Salmonella typhi</i>	Typhoid fever
<i>Shigella</i> spp.	Shigellosis
<i>Vibrio cholerae</i>	Cholera (Asiatic cholera)
<i>Vibrio parahaemolyticus</i>	Gastroenteritis
<i>Yersinia enterocolitica</i>	Yersiniosis (bloody diarrhea)

Escherichia coli

It is one of the most important members of the intestinal family and grows like a normal flora in the digestive system. It is also a pathogenic opportunistic bacterium, as it causes diarrhea as well as many diseases outside its natural habitat, including meningitis for newborns, septicemia, and urinary tract infection (Chauhan and Jindal, 2020). Gram-negative bacilli, movable by peripheral flagella surrounding the whole body and not forming spores, their colonies smooth and convex, not mucous, or mucous when having the capsule

structure, shiny pink on the medium of MacConkey agar, metallic green on the medium of eosin, methylene blue, non-dissolving gelatin and not producing sulfide gas. Hydrogen H₂S in a triglyceride medium grows at pH (4.4-9) and the optimum temperature for its growth is (36-37) (Wong et al., 2000). *E. coli* produces enterotoxins, the bacterial antigen is "O" type, flagellated antigen is "H" type, and surface antigen is "K" type. According to different antigen structures, bacteria serotypes can be divided into more than 180 types. Some highly pathogenic strains, capable of excreting endotoxins, cause diseases through contamination of drinking water and food (Todar, 2008).

The presence of pathogenic *E. coli* is usually reported in wastewater, some strains of pathogenic *E. coli* are found during treatment stages of wastewater plants (Anastasi et al., 2012). The amount of *E. coli* O157:H7 is about 10-102 CFU /100 ml for municipal wastewater and 102-103 CFU/100 ml for animal wastewater from slaughterhouses (Garcia Aljaro et al. 2005).

Salmonella enterica serovar Typhi

One of the most important problems facing health organizations and institutions in the world is typhoid fever and typhoid fever, which is one of the systemic infectious diseases that affect humans only, caused by *Salmonella enterica* of the type typhi. Food, contaminated water, and people who are carriers of the disease are the main source of infection. The genus *Salmonella* is one of the largest genera of the Enterobacteriaceae family. It is a gram-negative motile bacterium. Non-motile strains can also be found, not forming spores. *Salmonella* grows at pH between 8-6 and a temperature between (15-41). The optimal is 37 m. *Salmonella* bacteria have several properties by causing an infection called virulence factors. These traits include the ability to invade cells and be many copies in them, the ability to produce enterotoxins, and the ability of virulence antigens. Eating food or drinking water contaminated with this bacterium leads to infections in the stomach and intestines, which in turn constitutes the highest infection rates in the world (Dougan and Baker, 2014). It has the ability to move from irrigation water to edible plant parts (Lapidot and Yaron, 2009). The number of copies that can cause disease is 20 cells per milliliter. Pathogenic *Salmonella* strains were isolated from wastewater, sludge, and the most common serotypes are *Salmonella hadar* (38.1%), Then *Salmonella enteritidis* (23.8%), *Salmonella london* (14.3%), *Salmonella anatum* (9.5%) in raw and treated wastewater (Espigares et al., 2006).

Shigella dysenteriae

It belongs to the genus Intestinal *Shigella*, a Gram-negative bacterium that does not contain spores. Facultative anaerobic cold-resistant *S. dysenteriae* is the most common pathogenic bacteria that cause dysentery in humans. Symptoms are diarrhea, abdominal pain, and fever (Athman et al., 2008). *Shigella dysenteriae*, the most virulent of bacteria, is widely

distributed in sewage, which serves as its reservoir. For example, incidence rates of *Shigella* dysentery are as high as 40-60% in sewage and water bodies in South Africa. (Teklehaimanot, 2015). *Shigella dysenteriae* was also detected in 35 wastewater samples collected from hospitals and residential areas and *Shigella dysenteriae* was isolated from water and riverbed sediments in South Africa (Ekwanzala et al. 2017).

Vibrio cholerae

Vibrio cholerae, a member of the family Vibrionaceae able to improve respiratory metabolism and fermentation, Gram-negative bacteria, Vibrio-like, facultative anaerobic, having a single flagellum at one pole, non-forming spores present in various forms when exposed to harsh environmental conditions (WHO, 2004).

Halophilic able to survive in water with salt and dependent on aquatic organisms and plankton, chitin may be in the zooplankton surface as a carbon and nitrogen source for growth (Kim, et al, 2005). Some strains of *Vibrio cholerae* can cause cholera, an acute infection of the intestine. *Vibrio cholerae* can be divided into more than 200 serotypes, corresponding to the O antigens present on the lipopolysaccharides of the cell membrane. After ingestion by humans, *Vibrio cholerae* enters the small intestine through the oral cavity and gastric juice and then colonizes the mucus layer. to the virulence of cholera (Wang, 2015). An outbreak of *Vibrio cholerae* was observed in four wastewater treatment plants located in Gauteng Province, South Africa (Dungeni et al. 2010). Strains of pathogenic cholera bacteria were detected in household wastewater with an average range of 2.5×10^{-1} - 1.7×10^3 MPN. An elevated incidence of *V. cholerae* and other pathogens was verified in the wastewater and effluents of five wastewater treatment plants located in South Africa over a 12-month period (Nongogo and Okoh, 2014).

Common viruses in wastewater

A type of viruses that directly causes harm for health is found in wastewater. Viruses are widespread and spread in the environment by untreated discharge or treated wastewater (Bofill-Mas et al., 2010). A number of viruses like enterovirus, hepatitis virus, rotavirus, coronavirus, adenovirus, parvovirus, are present in wastewater.

Enterovirus

It is a kind of RNA virus associated with several human diseases that primarily affect the intestines. Enteroviruses are highly ability to spread and are transmitted primarily through taking contaminated food, water, and the respiratory tract (droplets, coughs, etc.). Worldwide distributed, enteroviruses are some viruses that are most resistant to normal conditions and disinfectants than bacteria (Hu et al. 2011). Enterovirus can stay alive in wastewater for several months. Enterovirus

is one of the most studied viruses in aquatic virology (Battistone, 2014).

Hepatitis virus

It is the pathogen that causes viral hepatitis, considered a major public health problem affecting humans in all countries and considered human morbidity and mortality. Hepatitis viruses are highly resistant to common chemical disinfectants and can live for months or years in a dry or frozen state in the environment. Human hepatitis viruses include hepatitis A virus (HAV), hepatitis B virus (HBV), hepatitis C virus (HCV), hepatitis D virus (HDV), and hepatitis E virus (HEV) (Lin&Kao, 2017). HAV and HEV are spread by intestinal infection, and other viruses are transmitted through the blood and other body fluids. HAV is a small molecule RNA virus that differs from other members of the picornavirus family in morphology and causes infectious or hepatitis C by the fecal-oral route. HBV, is a double-stranded DNA virus and belongs to the hepadnavirus group and is endemic in humans and hyperendemic in the world. Hepatitis B virus is resistant to relatively high environmental factors in the laboratory, its activity is inactivated by ultraviolet light, heat, and chemical disinfectants (such as phenol), it is widely distributed in wastewater.

Coronavirus

Coronavirus (CoV), is a variety of Coronaviridae family from order Nidovirales, contains 4 genera (β -CoV, α -CoV, Y-CoV, and -CoV&) that mainly infect β -CoV, α -CoV, and mammals. The enveloped virus is about 60,200-nm in diameter, with an average diameter of about 100-nm. The linear, single-stranded genome is approximately 1230 kb in length, so CoV is the tallest single-positive RNA virus in the whole genome. The composition and expression of the genomes of all CoVs are the same. The Nucleocapsid protein is the major protein of CoV and also the abundant protein in CoV-coding protein, exhibiting multiple functions in reproduction and immunity. Since the emergence of severe respiratory disease coronavirus (SARS) in 2003, the search for CoV has become a global concern (Zhong et al., 2003). Due to changing environmental conditions, the influence of immunity, or other causes, new strains of CoV has emerged. New coronaviruses have been identified successively, such as MERS-CoV and swine delta CoV, and emergence and re-emergence of these new coronary viruses causes high rates of disease and death in humans and animals and poses a major public health threat and heavy economic losses (Li et al., 2016). The virus can be transmitted, in addition to respiratory droplets, via feces in wastewater (Wang et al., 2020). Another study showed that SARS-CoV RNA may be detected in sanitation centers before and sometimes after disinfection despite the absence of SARS-CoV (Medema et al., 2020; Wu et al., 2020).

Norovirus

It is an RNA virus of the family Caliciviridae, has five genera (Vesivirus, Lagovirus, Nebovirus, Sapovirus, and Norovirus).

Genus Norovirus contains five genotypes (GI-V). Among five genotypes, GI, GII, and GIV can cause an infection for humans and cause acute gastroenteritis, and GII and GIII and GV have been isolated from pigs, cattle, sheep, and mice respectively. Norovirus is the major source of gastroenteritis in developing countries (Thorne and Goodfellow, 2014). Transmitted via faeces, norovirus infection is contacted with several diseases and clinical symptoms, such as enterocolitis, epilepsy encephalopathy in children, emphysema, and intermittent intravascular coagulation (Chan et al., 2010). In moderating countries, norovirus causes approximately of the 200,000 deaths of children under five years old yearly. Recent researchers refer that norovirus is the second cause that leads to gastroenteritis-related deaths in the USA, resulting in approximately 797 deaths yearly (Papafragkou et al, 2013). A previous study revealed norovirus gene clusters I (GI) and II (GII) in wastewater in France and are removed by waste stabilization pond treatment systems, activated sludge, and submerged membrane bioreactors (da Silva, 2007).

Common pathogenic protozoa in wastewater

Compared with water-borne epidemics caused by inorganic toxins, organic pesticides, and bacteria, the diseases caused by pathogenic protozoa such as Giardia and Cryptosporidium are characterized by characteristics, high disease prevalence, and a high number of patients. It can be seen that the primary pathogenic organisms and the main causes of waterborne diseases are among the different pathogenic microorganisms as shown in Table 3 (King, 2017).

Table 3. Waterborne Parasitic Protozoan Diseases

Organism	Disease (site affected)	Major Reservoir
<i>Balantidium coli</i> (cilia)	Dysentery/intestinal ulcers (Gastrointestinal tract)	Human feces
<i>Cryptosporidium</i> Coccidium	Cryptosporidiosis Gastrointestinal tract	Human and animal feces
<i>Entamoeba histolytica</i> Pseudopodia	Amoebic dysentery (gastrointestinal tract)	Human feces
<i>Giardia lamblia</i> Flagella	Giardiasis	Human and animal feces
<i>Naegleria gruberi</i> pseudopodia	Amoebic meningoencephalitis (central nervous system)	Soil and water

Protozoa of wastewater treatment

Protozoa play an environmental role not only in material recycling and self-purification in a normal ecosystem but also in the artificial systems of wastewater treatment plants. Activated sludge, wastewater treatment used in all parts of the world, has a flocculant structure with live protozoa. 230 species of protozoa found and can be observed in a system of activated sludge, including Mastigophora, Peranema deflexum, Anisonema, acinus, Sarcodina, M. penardi and A.

hemisphaerica) ciliates and others. The giants add seventy percent of total protozoa in the sludge during the sewage purification process. Protozoa organisms are responsible for making quality and safety of effluents by maintaining density of bacteria in wastewater. Role of protozoa in wastewater treatment:

1. Use of organic materials in wastewater directly.
2. Enhance the flocculation process.
3. Able to ingest bacteria and other microorganisms.

Protozoa have a faster rate of bacterial eating and a shorter generation time. Its feeding range is not wide, it mainly feeds on bacteria, therefore it is not a good choice to be the main predator in the sewage treatment system.

Some types of protozoa that are found in sewage water

Cryptosporidium parvum

They are intestinal parasites and are a major cause of gastrointestinal diseases in children worldwide (Reh et al., 2019). It is more pronounced in children under the age of two years who have a less developed immune system than in adults (Delahoy et al., 2018). It poses a danger to children in poor areas in particular, as it is the second cause of death associated with diarrhea after rotavirus, especially in children under five years of age (Kotloff et al., 2013). *C. parvum* causes damage as it causes inflammation of the intestinal epithelium resulting in malabsorption and increased intestinal secretions leading to diarrhea, dysentery, vomiting, and nausea that may last more than seven days. This situation may lead to death in severe cases and persistent diarrhea in very young children and immunocompromised patients (Ferguson, 2018). Although several *Cryptosporidium*-species has been conducted in humans, *C. hominis* and *C. parvum* that are more than 90% present in humans when infected with Cryptosporidiasis (Chalmers et al., 2011). The parasite *C. parvum* can complete its entire life cycle in one host, where the infected host secretes eggs with faeces. These eggs are resistant to environmental conditions and contain four sporozoites within them. At this time, the egg begins the infective cycle to start causing the disease to the host by the route of exit of sporozoites from eggs into the intestinal lumen (O'Hara and Chen, 2011). Temperature and pH affect the exit of these sporozoites (Hijjawi et al., 2001), as they attack the epithelial cells of the small intestine (Ward and Anoli, 2010) and then turn into merozoites, which in turn into small gametes and large gametes, and their union produces the egg. The fertilized Zygote, which produces thin-walled and thick-walled eggs, and then turns into sporozoites (Chiodini et al., 2003). After that, the process of sexual reproduction takes place, which produces large numbers of eggs, which are later excreted with the faeces, which are contagious after leaving the body of the host directly. It begins by infecting another host through oral transmission of feces containing it (Ward and Anoli, 2010). *Cryptosporidium* is seriously harmful to drinking water. Compared to Giardia, Amoeba, Toxoplasma, Neisseria, and Cyclospora, *Cryptosporidium* lives longer in the environment and is

resistant to chemical disinfectants. It is difficult to remove by filtration and disinfectant chemicals. Cryptosporidium is therefore considered an indicator of protozoan pathogens in the public water supply system (WHO, 2009).

Giardia lamblia

G. lamblia is one of the most prevalent primary parasites that infect humans on a wide scale in almost all countries of the world (Chabra et al., 2019). It is found in the small intestine of humans and other mammals and causes giardiasis (Bond et al., 2015). *G. lamblia* is called by other names, including *G. duodenalis* or *G. intestinalis*, and is exacerbated and infects humans and animals, where it is a cause of intestinal disorders (Lee et al., 2018). *Giardia* is a major cause of steatorrhea almost all over the world (Cabrera-Licona et al., 2017). In the small intestine, after ingestion, *Giardia* cysts release the active phase, trophozoite, which causes symptoms including diarrhea, abdominal pain, malabsorption, and weight loss. Cysts have a hard cyst wall that enables them to withstand harsh environmental conditions when they are excreted with faeces (Adam, 2001). Intestinal protozoan parasites are among the major contributors to gastrointestinal diseases that cause significant social and economic consequences worldwide (Seguim, et al., 2018).

Entamoeba histolytica

The histolytic amoeba *E. histolytica* is a unicellular parasite that moves quickly and can change shape (Dufour et al., 2015). The histolytic amoeba *E. histolytica* possesses several phases during its life cycle, which are the trophozoite phase, the pre-cyst phase, the cyst phase, and the post-metacystic phase. In general, the diameter of the trophic phase ranges between (20-30 µm), but sometimes it may be less than 10 micrometers and may reach more than 60 micrometers. When the mature pouches are eaten with food and drink, they will pass through the stomach, the amoeba does not show any activity in the acidic medium, but when it reaches the basal medium in the small intestine, the multinucleated amoeba comes out through a small hole and escapes from the excystation. Then followed by direct division of the nucleus and cytoplasm to form eight small amoebae called Cystic trophozoite, which are similar in the characteristics of the adult feeding role except for their size. These amoebae do not settle in the intestine but pass with food to the large intestine (Samie, et al., 2012). The trophic phases may live and multiply within the crypts of the mucous of the large intestine that is fed by starches and mucous secretions. The trophic phases usually begin with tissue invasion when the mucosal cells are degraded by a few lysis enzymes and absorb the degraded product forming ulcers in the intestinal wall, and eventually reach the submucosal layer and spread aside in the submucosal layer forming a flask-shaped ulcer. The ulcer may develop in the cecum, appendix, ascending colon, ileocecal valve, terminal ileum intestine, sigmoid colon, and rectum and may reach the lower blood vessels, and from here it may travel with the blood to other sites outside the intestine, for example, the liver, lungs or The brain or the

skin (Roberts and Janovy, 2005). This organism may be found in all types of polluted water (Begum et al., 2015).

Table 4. The main helminths in the environment (Cohen et al., 2017)

Classification of helminths	Host organs	Major helminthes
Flukes (trematodes)	Intestinal	<i>Fasciolopsis buski</i> <i>Echinostoma ilocanum</i> <i>Heterophyes heterophyes</i> <i>Metagonimus yokogawai</i>
	Liver/lung	<i>Clonorchis (opisthorchis) sinensis</i> <i>Opisthorchis viverrini</i> <i>Fasciola hepatica</i> <i>Paragonimus westermani</i> <i>Paragonimus mexicanus</i> <i>Paragonimus heterotremus</i> <i>Paragonimus skrjabini</i> <i>Paragonimus spp.</i>
	Blood	<i>Schistosoma mansoni</i> <i>Schistosoma haematobium</i> <i>Schistosoma japonicum</i> <i>Schistosoma intercalatum</i>
Tapeworms (cestodes)	Intestinal	<i>Schistosoma mekongi</i>
	Tissue	<i>Diphyllobothrium latum</i> <i>Dipylidium caninum</i> <i>Hymenolepis nana</i> <i>Hymenolepis diminuta</i> <i>Taenia solium</i> <i>Taenia</i>
Roundworms (nematodes)	Intestinal	<i>Saginata</i> <i>Taenia solium</i> <i>Echinococcus granulosus</i> <i>Echinococcus multilocularis</i> <i>Multiceps multiceps</i> <i>Taenia multiceps</i> <i>Spirometra mansonoides</i> <i>Diphyllobothrium spp.</i> <i>Ascaris lumbricoides</i> <i>Enterobius vermicularis</i> <i>Ancylostoma duodenale</i> <i>Necator americanus</i> <i>Strongyloides stercoralis</i> <i>Trichostrongylus spp.</i> <i>Trichuris trichiura</i> <i>Capillaria philippinensis</i>
	Tissue	<i>Trichinella spiralis</i> <i>Visceral larva migrans</i> (<i>Toxocara canis</i> or <i>Toxocara cati</i>) <i>Ocular larva migrans</i> (<i>Toxocara canis</i> or <i>Toxocara cati</i>) <i>Dracunculus medinensis</i> <i>Neural larva migrans</i> (<i>Baylisascaris procyonis</i>) <i>Angiostrongylus cantonensis</i> <i>Angiostrongylus costaricensis</i> <i>Gnathostoma spinigerum</i> <i>Anisakis spp.</i> (larvae from saltwater fish) <i>Phocanema spp.</i> (larvae from saltwater fish) <i>Contracaecum spp.</i> (larvae from saltwater fish) <i>Capillaria hepatica</i>
	Blood and tissues	<i>Thelazia spp.</i> <i>Wuchereria Bancroft</i> <i>i</i> <i>Brugia malayi</i> <i>Brugia timori</i> <i>Onchocerca volvulus</i> <i>Mansonella ozzardi</i> <i>Mansonella streptocerca</i> <i>Mansonella perstans</i> <i>Dirofilaria</i> spp.

Helminths . parasitic worms

Term "helminth" from Greek origin "worm". There are two groups of parasitic worms, these groups are flatworms and nematodes. Flatworms consist of tapeworms (tapeworms) and trypanosomes (nematodes). Parasitic worms exist in two stages: the first stage is an actively growing larva or worm; the larva is found inside the host and makes eggs. The egg is the second instar and leaves the host, is excreted with the feces. The egg is a protective structure that is resistant to unfavorable conditions and can infect a new host. In the life cycle of helminths, there may be more than one intermediate host. The larva or egg lives in the middle host. Humans can be the intermediate host of larvae. The human larvae are the caudate larvae of the pork tapeworm *Taenia solium*. Parasitic worms include many worms that are important parasites of humans and animals. Many parasitic worms are transmitted through human and animal waste. The main parasitic worms of interest to workers in sewage (wastewater). Most surveys of wastewater parasites identified the presence or absence of parasitic stages. Wastewater contains the main types of parasites (Jia and Zhang, 2020).

Classification of helminthes

The final classification of helminths depends on the external and internal form of their adult stage, larvae, and eggs. Most helminths are found in three main groups: flukes trematodes, tapeworms (cestodes), and nematodes (Castro, 1996). The subdivision depends on the host organs. Table 4 shows from previous studies (Cohen et al., 2017) summarizes the main parasitic worms in the environment. Trypanosoma worms are leaf-shaped worms, which are about a few mm to eight cm. Trypanosoma is hermaphrodite except blood trypanosomes, which are bisexual. Larvae through many larval steps before maturation. Tapeworms (tapeworms) are hermaphrodites and about (2mm-10m) mm in length, adult tapeworms are flat, adult roundworms (nematodes), cylindrical in shape, usually bisexual. Most nematodes live in the intestine and extra-intestinal places. The main developmental stages of nematodes include (eggs, larvae, and adult stage). The concentration of eggs is so high in wastewater and sludge, especially in moderating countries (Amoah et al., 2018). Eggs were found when irrigating the soil with sewage that transmit helminth infection among farmers of plants in Ghana (Amoah et al, 2016). Raw and treated wastewater samples conducted from 8 WWTPS stations in Tehran and two in Isfahan were explored for helminth eggs during the period 2002-2003, which showed that egg level was high in effect after wastewater treatment, moreover Furthermore, helminth eggs are one of the major contaminants and must remove from wastewater reused for agriculture, aquaculture, and their fate should further investigated during different wastewater processes of treatment (Jimenez, 2007).

Conclusion

Production of reused water is the treatment for pathogen removal or inactivation. While chemical contaminants are

also important, health regulators tend to focus on contaminants that cause acute disease, especially in the context of nonpotable reuse of wastewater when chronic human exposure is unlikely.

The fate of pathogens in water is associated with particles. It is therefore important to understand the nature of pathogen–particle associations, the factors influencing the formation and stability of the association, and how the association affects treatment disinfection processes.

Various particle characteristics such as shape, size, composition, and structure all play important roles in the association process.

Similarly, there have been studies on the impact of particles on the disinfection of some pathogens or pathogen indicators in wastewater.

A better understanding of this behavior may identify ways to modify processes to alter pathogen partitioning or identify other treatment strategies for dealing with particle-associated pathogens.

Controlling pathogen–particle associations provides an opportunity to enhance wastewater treatment and reduce treatment costs.

Increased levels of association can enhance removal by sedimentation processes.

Reduced levels of association can enhance disinfection.

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