REVIEW

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A Comprehensive Review of Waterborne Viral Infections and their Public Health Implications

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ABSTRACT

Waterborne viral diseases remain a major public health burden and a leading cause of mortality across all age groups, particularly in developing countries where access to safe water and sanitation is limited. These infections commonly manifest as gastroenteritis and are caused by viruses such as hepatitis A and E viruses, poliovirus, rotavirus, coxsackievirus, adenovirus, norovirus, and astrovirus. Clinical symptoms typically include nausea, vomiting, diarrhoea, abdominal cramps, fever, fatigue, and, in some cases, jaundice. Transmission occurs predominantly through the faecal–oral route, often via ingestion of contaminated water or food, as well as through direct contact with infected individuals or contaminated surfaces. The persistence and spread of these pathogens are closely linked to poor hygiene practices, inadequate waste disposal, and insufficient water treatment systems. Effective prevention strategies include the provision of clean and safe drinking water, improved sanitation infrastructure, vaccination programs, proper food handling, safe water storage, routine water quality testing, and continuous public health education. Early detection and appropriate clinical management are also essential in reducing morbidity and mortality associated with these infections. This review provides a comprehensive overview of the epidemiology, transmission pathways, clinical manifestations, and pathogenesis of common waterborne viral diseases, alongside current preventive and therapeutic approaches. Addressing this global health challenge requires coordinated efforts from local communities, governments, and international health organizations to implement sustainable interventions and strengthen public health systems.

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Epidemiology, Global health challenge, Preventive approach, Public health systems, Viral pathogen.

1. Introduction

A waterborne disease is an illness caused by microorganisms that are transmitted through contaminated water (Department of Health, 2022; Okwonkwo *et al.* 2026; Okoye *et al.* 2026). These microorganisms can include bacteria, viruses, and parasites. Examples of waterborne diseases include cholera, typhoid fever, giardiasis, cryptosporidiosis, and dysentery (Uba *et al.*, 2017; Dokubo *et al*. 2022a; 2022b; Anidu *et al*. 2023). Viruses are the tiniest microorganisms of all parasites, with an approximate size ranging from 0.03 to 0.1 µm. Viruses are present in drinking water sources but their impact on human health is less widely understood and acknowledged (Okafor *et al*. 2023; Uba and Obiefuna, 2023; Ubani *et al.*, 2025). However, swallowing them can have major health consequences (Gall *et al.*, 2015; Adelodun *et al.*, 2021; Ibe *et al*. 2023, Alfred *et al*. 2023; 2025; Chukwura *et al*. 2025; Okpalaunegbu *et al*. 2025; Okolo *et al*. 2025).

Waterborne viruses can enter the body through ingestion of contaminated water, consumption of contaminated food washed with contaminated water, or contact with contaminated water during recreational activities (Ramirez-Castillo *et al.*, 2015; Obiefuna *et al.* 2025). When untreated or poorly treated water is consumed, it can lead to infections and diseases in humans and animals (Mundi *et al*. 2014a; 2014b; Okoye *et al*. 2014; Uba *et al*. 2016; Anameze *et al*. 2023).

Water-borne viral diseases are major public health concerns, as they can cause widespread illness and even death (Annan *et al.*, 2018; Obiefoka *et al.*, 2023; Uba *et al.*, 2024). Water-borne viral diseases can have a severe impact on national economies. Outbreaks can lead to lost productivity, increased healthcare costs, and a decline in tourism (McKee and Cruz, 2021; Ele *et al.*, 2025; Uba *et al.*, 2026a; 2026b; 2026c). Water-borne viral diseases disproportionately affect vulnerable populations such as children, pregnant women, the elderly, and those living in poverty (McKee and Cruz, 2021; Dokubo and Uba, 2023; Ubani *et al.*, 2024a; 2025b).

Outbreaks of water-borne viral diseases can overwhelm healthcare systems and cause shortages in medical supplies. Water-borne viral diseases can also damage the environment (Uba, 2019; Uba *et al*. 2021; Egurefa *et al*. 2020a; 2020b). For example, the improper disposal of contaminated waste can lead to the spread of disease and environmental pollution. Understanding and preventing water-borne viral diseases is critical for protecting public health, promoting social justice, ensuring economic stability, and protecting the environment (Ibo *et al*. 2020; Umeh *et al.*, 2020; 2021; Nwigwe *et al*. 2022, Nwigwe *et al*. 2023).

The aim of this review is to examine the epidemiology, transmission, clinical features, pathogenesis, prevention, and management of common waterborne viral diseases, with a view to informing effective control and public health interventions.

2. Overview on Waterborne Viral Diseases

2.1 Common Waterborne Viral Diseases

Water-borne viral diseases are spread by viruses that are transferred to humans through contaminated water. Some of the most common waterborne viral diseases are:

2.1.1 Hepatitis A

Hepatitis A is a viral infection caused by the hepatitis A virus (HAV) that affects the liver. The hepatitis A virus (HAV) belongs to the *Hepatovirus* genus within the *Picornaviridae* family (Wang *et al*., 2015). HAV was first isolated in 1979. Humans are the only natural hosts, although several nonhuman primates have been infected in laboratory conditions. Depending on conditions, HAV can be stable in the environment for months. The virus is relatively stable at low pH levels, moderate temperatures, and frozen temperatures, but can be inactivated by high temperature (185°F [85°C] or higher), formalin, and chlorine (Migueres *et al*., 2021).

2.1.1.1 Transmission

HAV infection is acquired primarily by the fecal-oral route by either ingestion of contaminated food or water or direct contact with an infectious person. Since the virus is present in the blood during the illness prodrome, HAV has been transmitted on rare occasions by blood transfusion as well as solid organ transplantation. Although HAV may be present in saliva, transmission by saliva has not been demonstrated. Waterborne outbreaks are also recorded and are usually associated with sewage-contaminated or inadequately treated water. (WHO, 2023a).

2.1.1.2 Epidemiology

The incidence of hepatitis A varies considerably between countries depending on the socio-demographic index (Zeng *et al*., 2021). Low- and middle-income countries, mainly in Africa and South Asia, have the greatest hepatitis A burdens (Jacobsen, 2018). However, there are estimated to be 100 million HAV infections and 1.5 million symptomatic cases annually worldwide, and these are responsible for 15,000 to 30,000 deaths per year (WHO, 2019). The endemic nature of HAV is classified according to age-specific prevalence into high ($\geq$ 90% by age 10 years), intermediate ($\geq$ 50% by age 15 years with $<$ 90% by age 10), low ($\geq$ 50% by age 30 with $<$ 50% by age 15), and very low ($\leq$ 50% by age 30). Infection rates remain low in areas where HAV is rare due to poor HAV circulation despite low immunity rates as long as the disease is not introduced from an external source (WHO, 2019). Some outbreaks have occurred, mainly in individuals at specific risk.

2.1.1.3 Symptoms

Symptoms of hepatitis A include fatigue, nausea, vomiting, abdominal pain, and jaundice (yellowing of the skin and eyes). Some people may not experience any symptoms, while others may experience severe symptoms that can last for months. Hepatitis A is usually a self-limiting disease, meaning that it goes away on its own without treatment. However, in rare cases, it can cause serious complications such as liver failure, especially in older adults or people with pre-existing liver diseases (Aggarwal, 2011).

2.1.1.4 Pathogenesis

HAV is typically acquired through ingestion (through fecal-oral transmission) and replicates in the liver. After 10 to 12 days, the virus is present in the blood and is excreted via the biliary system into the feces. Peak titers occur during the 2 weeks before the onset of illness. Although the virus is present in serum, its concentration is several orders of magnitude less than in feces. Virus excretion begins to decline at the onset of clinical illness and decreases significantly by 7 to 10 days after the onset of symptoms. Most infected persons no longer excrete the virus in their feces by the third week of illness (Foster *et al*., 2018).

2.1.1.5 Diagnosis

Biological diagnosis is required because hepatitis A is clinically indistinguishable from other viral forms of hepatitis. Acute hepatitis A is mainly diagnosed by demonstrating anti-HAV IgM. Anti-HAV IgM antibodies appear a few days before or concurrently with the onset of clinical symptoms. Their titre remains high for about 1 month and then gradually decreases to zero over about 6 months in most patients (WHO, 2019). False-positive results can occur due to specificity problems, and anti-HAV IgM can also be detected following vaccination. Therefore, this analysis should only be conducted when it is clinically suspected (CDC, 2005). Anti-HAV IgG antibodies appear soon after the IgM antibodies and persist for many years, conferring lifelong immunity. Their presence indicates past, resolved infections (Nelson *et al*., 2020).

Another type of diagnosis that can be done is the Nucleic acid amplification test, but it is rarely used. They can detect HAV RNA in the feces and plasma of patients who have been infected (Costa-Mattioli *et al*., 2002), and in contaminated water and food (Lowther *et al*., 2019). Sequencing and phylogenetic analysis are mainly used to track outbreaks, and these techniques are particularly useful for identifying transmission routes.

2.1.1.6 Prevention

Prevention measures include vaccination, practising good hygiene, avoiding contaminated food and water, and washing hands thoroughly after using the toilet, changing diapers, or handling food (Kim *et al*., 2021). Countries with inadequate sanitation

and poor hygiene practices are more prone to hepatitis A outbreaks. Travelers to these areas should take extra precautions and consider getting vaccinated before their trip. Hepatitis A is a preventable disease, and appropriate vaccination, good hygiene practices, and safe food handling can help reduce the risk of infection (Gullon *et al*., 2017).
Post-exposure prophylaxis requires giving inactivated vaccine to all people who are unvaccinated (>12 months) within 2 weeks of exposure.

2.1.1.7 Treatment
There is no specific treatment exists for hepatitis A; supportive care is given, such as resting, eating a well-balanced diet, and adequate fluid intake.

2.1.2 Hepatitis E
Hepatitis E is the liver inflammation caused by the hepatitis E virus (HEV). The virus has at least 4 different types: genotypes 1, 2, 3 and 4. Genotypes 1 and 2 have been found only in humans. Genotypes 3 and 4 circulate in several animals including pigs, wild boars and deer without causing any disease, and occasionally infect humans.

2.1.2.1 Transmission
The virus spreads predominantly by the fecal–oral route. The outbreaks usually follow periods of fecal contamination of drinking water supplies and may affect several hundred to several thousand persons (Yekta *et al*., 2021). The illness is usually self-limiting and resembles other hepatotropic viruses. However, in some cases, the condition progresses to severe liver failure. In areas with better sanitation and water supply, hepatitis E infection is infrequent, with only occasional sporadic cases '(WHO, 2022). Most of these cases are caused by genotype 3 virus and are triggered by infection with virus originating in animals, usually through ingestion of undercooked animal meat (including animal liver, particularly pork). These cases are not related to contamination of water or other foods. (Magana-Arachchi and Wanigatunge, 2020).

2.1.2.2 Epidemiology
Hepatitis E is extremely prevalent in certain underdeveloped nations where drinking water might be contaminated (Aggarwal, 2011; Magana-Arachchi and Wanigatunge, 2020). It manifests itself as outbreaks and occasional instances of acute hepatitis in these highly endemic locations.
The disease is endemic in the Indian subcontinent, China, Southeast and Central Asia, the Middle East and northern and western Africa (Yekta *et al*., 2021). Hepatitis E outbreaks of various magnitudes have been documented in these regions. Furthermore, hepatitis E virus infection is responsible for a substantial number of sporadic acute hepatitis cases in these locations.

2.1.2.3 Symptoms
Symptoms include the initial phase of mild fever, reduced appetite (anorexia), nausea and vomiting lasting for a few days; abdominal pain, itching, skin rash, or joint pain, jaundice (yellow colour of the skin), dark urine and pale stools; and a slightly enlarged, tender liver (hepatomegaly). In rare cases, acute hepatitis E can be severe and result in fulminant hepatitis (acute liver failure) (WHO, 2023b)

2.1.2.4 Pathogenesis
The HEV first replicates in the intestinal tract before reaching the liver via the blood in a quasi-enveloped form. It then replicates in the cytoplasm of hepatocytes and is released as lipid-associated particles into the blood and bile. Bile salts then strip the lipids from the virus shed in the stool. Since HEV is not cytopathic, the liver damage induced by an HEV infection may be immune-mediated by cytotoxic T cells and natural killer cells (Lhomme *et al*., 2020).

2.1.2.5 Diagnosis
Cases of hepatitis E are not clinically distinguishable from other types of acute viral hepatitis. However, diagnosis can often be strongly suspected in proper epidemiologic settings. Definitive diagnosis of hepatitis E infection is usually based on detecting specific anti-HEV immunoglobulin M (IgM) antibodies to the virus in a person's blood; this is usually adequate in areas where the disease is common. Additional tests include reverse transcriptase polymerase chain reaction (RT-PCR) to detect the hepatitis E virus RNA in blood and stool. This assay requires specialized laboratory facilities. This test is particularly needed in areas where hepatitis E is infrequent and in uncommon cases with chronic HEV infection (WHO, 2023b).

2.1.2.6 Prevention
Prevention is the most effective approach against HEV infection. At the population level, hepatitis E infection can be reduced by maintaining quality standards for public water supplies and establishing proper disposal systems for human feces. On an individual level, infection risk can be reduced by maintaining hygienic practices; and avoiding consumption of water and ice of unknown purity (Lhomme *et al*., 2020).

2.1.2.7 Treatment
There is no specific treatment for acute hepatitis E. As the disease is usually self-limiting, unnecessary medications that can adversely affect liver such as paracetamol is discouraged. Hospitalization is required for people with fulminant hepatitis and should also be considered for symptomatic pregnant women. Immunosuppressed people with chronic hepatitis E benefit from

specific treatment using ribavirin, an antiviral drug. In some specific situations, interferon has also been used successfully (Wedemeyer *et al*., 2012).

2.1.3 Polio

Polio, short for poliomyelitis, is a highly infectious viral disease caused by the poliovirus. Poliovirus, the virus causing acute polio and post-polio syndrome, is a member of the Picornaviridae family and belongs to the Enterovirus C species. There are 3 serotypes of wild poliovirus: types 1, 2, and 3 (Brown *et al*., 2003). Wild poliovirus 1 was the primary cause of most of the world's paralytic polio cases until vaccines became widespread. Wild types 2 and 3 are considered eradicated as of 2015 (Greene *et al*., 2019).

2.1.3.1 Transmission

The virus spreads through contaminated food and water or via contact with an infected person's feces. Polio also spreads through coughing or sneezing. It can spread by not washing hands after going to the bathroom or touching poop (like changing diapers), drinking contaminated water or getting it in your mouth, eating foods that have touched contaminated water, or swimming in contaminated water. Water can become contaminated when someone who has diarrhoea swims in it (WHO, 2023c).

2.1.3.2 Epidemiology

Before global health initiatives, nearly 1 in 200 patients with poliomyelitis developed permanent paralysis. In 1988, 350,000 cases of endemic poliomyelitis spread across 125 countries (Al Awaidy and Khamis, 2020). That same year, the World Health Assembly set goals for completely eradicating wild-type polio. Since then, type 1 has been the only circulating wild type and is endemic only to Pakistan and Afghanistan, and sporadic outbreaks continue to occur. In late 2021 to early 2022, wild-type polio type 1 caused paralytic polio in Southeastern Africa. The outbreak was related to a virus traced back to Pakistan (Davlantes *et al*., 2023). Recent cases of type 2 polioviruses derived from oral vaccines are also increasing in sub-Saharan Africa and Asia (Greene *et al*., 2019). Some barriers to complete eradication include poor program compliance and access to healthcare in remote endemic areas. Routine childhood vaccination has been successful against the spread of the disease globally, with a 99% reduction in cases from the earlier stated 350,000 in 1988 to just 33 in 2018 (Al Awaidy and Khamis, 2020).

2.1.3.3 Symptoms

Symptoms may include fever, fatigue, headache, vomiting, and muscle pain or stiffness. In severe cases, the virus can lead to permanent paralysis or death, primarily in young children. It often attacks the central nervous system and can cause paralysis or even death (WHO, 2023c). Polio has three strains, and most infected people do not display any symptoms. However, in approximately 1% of cases, the virus can enter the bloodstream and affect the spinal cord and brain, causing paralysis (WHO, 2016).

2.1.3.4 Pathogenesis

Poliovirus primarily spreads via fecal-oral contamination, but oral-oral spread is also possible. Primary infection can lead to viral replication in oropharyngeal and gastrointestinal lymphatic tissues. Maximum viral excretion begins 2 to 3 days before symptoms start and continues for an additional week (Mehndiratta *et al*., 2014). In up to 95% of cases, infections are non-paralytic, presenting as a flu-like illness. In approximately 5% of cases, pure motor paralysis can occur. The spread of the virus to the central nervous system is poorly understood. If this spread occurs, the virus may cause anterior horn neuronal death, resulting in a physical exam consistent with intact sensation and pure motor deficits (Wolbert *et al*., 2024).

2.1.3.5 Diagnosis

Clinicians should have a high suspicion of viral meningitis when acute flaccid paralysis is present. Testing includes blood, cerebral spinal fluid, respiratory, stool viral cultures, and polymerase chain reaction to detect poliovirus or other viruses in the differential diagnosis. Electromyograms and brain/spinal cord magnetic resonance imaging can be obtained to rule out other pathologies. There are no definitive biomarkers widely accepted regarding post-polio syndrome. There is currently early research on potential biomarkers of post-polio syndrome in the cerebral spinal fluid using polymerase chain reaction (Gonzalez *et al*., 2009).

2.1.3.6 Prevention

The best way to prevent polio is vaccination, which is usually done in childhood and proper hygiene. As more communities worldwide oppose vaccinations, informing the public about the potentially deadly and disabling side effects of not receiving the polio vaccine can be helpful. The Global Polio Eradication Initiative partners with the World Health Organization, US Centers for Disease Control (CDC), Rotary International, United Nations Children's Fund, and the Bill & Melinda Gates Foundation to work for a polio-free world (Wolbert *et al*., 2024). The Polio Endgame Strategy has the following key components:

2.1.3.7 Routine immunization

1. Goal of greater than 80 % vaccination of all children in the first year of life
2. At least 3 doses of OPV (or IPV per current CDC recommendations) as part of the national immunization schedule.

2.1.3.8 Supplementary Immunization

1. Mass immunization campaigns are known as National Immunization Days
2. 2 rounds, 1 month apart from each other
3. Immunize all children younger than 5 with 2 doses of OPV, regardless of immunization status

2.1.3.9 Treatment

Fortunately, there is an effective vaccine for polio, and through global vaccination campaigns, the disease has been reduced by more than 99% worldwide since 1988. The Global Polio Eradication Initiative, a partnership between the World Health Organization, Rotary International, the US Centers for Disease Control and Prevention, and UNICEF, is working to eradicate polio (WHO, 2021). Although the disease is largely under control, cases can still occur in areas with low vaccination rates. Therefore, it is essential to continue vaccination efforts to protect future generations from this debilitating disease.

2.1.4 Norovirus

Norovirus is a highly contagious virus that can cause gastroenteritis, which is an infection of the stomach and intestines. It is the leading cause of gastroenteritis outbreaks, both in the community and in healthcare facilities (Capece and Gignac, 2023). Noroviruses are icosahedral viruses in the family Caliciviridae, with a single-stranded, positive-sense RNA genome (Atmar, 2010).

2.1.4.1 Transmission

Norovirus is transmitted through the fecal-oral route, primarily through contaminated food or water, or by contacting an infected person or contaminated surfaces. The virus can survive on surfaces for long periods, making it highly transmissible (Atmar *et al*., 2018). The virus spreads directly from person to person or indirectly through contaminated food or water (de Graaf *et al*., 2017). Infected individuals shed billions of viral particles per gram of stool or vomit, which can contaminate food, water, and surfaces. Vomiting can result in significant environmental contamination (Kirby *et al*., 2016), leading to transmission through fomites and airborne droplets.

2.1.4.2 Epidemiology

Globally, outbreaks of norovirus are usually more common in cooler winter months. They typically occur from November to April in countries above the equator, and from May to September in countries below the equator. However, in places closer to the equator, norovirus may be less seasonal. Since 2002, GII.4 viruses (genogroup II genotype 4) have caused most norovirus outbreaks worldwide. However, non-GII.4 viruses, such as GII.17 and GII.2, have temporarily replaced GII.4 viruses in several Asian countries. Between 2002 and 2012, the new GII.4 viruses emerged about every 2 to 4 years, but since 2012, the same virus (GII.4 Sydney) has been the dominant strain worldwide. Often, but not always, these new strains lead to a global increase in norovirus outbreaks (CDC, 2024).

2.1.4.3 Symptoms

Symptoms of norovirus infection include nausea, vomiting, diarrhoea, stomach cramps, and fever. These symptoms typically last for 24-48 hours and can also lead to dehydration. Individuals with weakened immune systems, young children and older adults are at a higher risk of developing complications from norovirus infection. While people with norovirus AGE typically recover quickly, viral shedding can persist for weeks after infection (Rockx *et al*., 2002). Norovirus AGE ranges in severity from mild to life-threatening, with young children, elderly, and immunocompromised individuals at the highest risk for severe disease.

2.1.4.4 Pathogenesis

Because of the lack of a cell culture system and the historical lack of animal models of norovirus infection, the extent of knowledge regarding pathogenesis is few. However, based on histological and biochemical studies of infected human volunteers, norovirus infection results in a mild inflammatory infiltration into the lamina propria. While specific intestinal lesions are observed during the time of norovirus illness, they completely resolve within two weeks. The outcome of infection is an alteration of gastric motor functions or inflammation of the pyloric junction between the stomach and intestine. Transient malabsorption of D-xylose, fat, and lactose also occurs during acute norovirus infection (Karst, 2010).

2.1.4.5 Diagnosis

Norovirus may be suspected based on symptoms, but routine testing is not usually conducted outside of outbreak investigations. Laboratory confirmation of norovirus is generally not necessary in clinical settings, although it may be useful in select situations, for example in immunocompromised patients with severe or persistent symptoms or for public health purposes during outbreaks of gastroenteritis. The most widely used method is reverse-transcription real-time polymerase chain reaction (RT-PCR) assays, which provide high sensitivity and specificity, can estimate viral load in stool samples, and can discriminate between pathogens. Enzyme immunoassays (EIAs) can also be used to diagnose norovirus acute gastroenteritis in stool samples but have poor sensitivity. Ideally, stool specimens should be collected < 2–3 days from symptom onset and frozen or refrigerated to ensure nucleic acid integrity (CDC, 2021).

2.1.4.6 Prevention

Preventive measures include regular washing of hands, and importantly, after using the toilet or changing diapers, before eating, preparing, or handling food and before giving yourself or someone else medicine. Carefully wash fruits and vegetables well. Routinely clean and sanitize kitchen utensils, cutting boards, counters, and surfaces, especially after handling shellfish. Clean and disinfect surfaces after someone vomits or has diarrhoea (CDC, 2024).

2.1.4.7 Treatment
There is no specific treatment for norovirus infection. The illness is usually self-limited and resolves on its own within a few days (McIntosh, 2018). Treatment focuses on managing symptoms and preventing dehydration through increased fluid intake. Good hygiene practices like frequent hand washing, cleaning and disinfecting surfaces, and minimizing contact with infected individuals are effective ways of preventing norovirus transmission. Vaccines against norovirus are being developed, but currently, no effective vaccine is commercially available (Gaythorpe *et al*., 2018).

2.1.5 Polyomavirus
There are five types of human polyomaviruses, BK virus (BKV), WU, KI, Merkel cell, and JC virus (JCV). Polyomaviruses are known to have very restricted host ranges; accordingly, BKV and JCV are only known to infect and cause disease in humans productively (Boothpur and Brennan, 2010). The genus of polyomaviruses belongs to the Papovavirdae family. Polyomaviruses are icosahedral, non-enveloped stranded circular super coiled viruses. They measure 40.5 – 44 nm in diameter and comprise 88% protein and 12% DNA (Prezioso *et al*., 2021).

2.1.5.1 Transmission
Transmission is through the feco-oral and respiratory routes. Other routes include blood transfusion, transplacentally, through semen, and organ transplantation. Transmission occurs mostly through close contact. Primary infection mainly occurs in childhood and is asymptomatic or minimally symptomatic. Asymptomatic shedding of these viruses in the urine can be seen in both healthy subjects and immunosuppressed patients, with asymptomatic JC and BK viruria seen in 3 % of pregnant patients (Zhou *et al*., 2023).

2.1.5.2 Epidemiology
Polyomaviruses are widespread and affect 80 % of the human population. They do not cause clinically significant infections in immunocompetent hosts (Boothpur and Brennan, 2010). The prevalence of BK and JC viral infection differs in geographical and age distribution suggesting they circulate independently. BK infection is acquired in early childhood whereas JC presents later, 3–4 years versus 10–14 years. Approximately 80 % of the adult population is seroprevalent for polyomaviruses (Blackard *et al*., 2020). In the general population, JC viruria is more common than BK viruria. In a recent study of healthy Swiss blood donors, the incidence of JC and BK viruria was 19% and 7%, respectively. In contrast, in immunocompromised patients, BK viruria is more common (Gorriceta *et al*., 2023).

2.1.5.3 Symptoms
After initial infection, both BK and JC viruses remain latent in different tissues (*vide infra*). For unknown reasons, BK viruria correlates with the degree of immunosuppression whereas JC viruria does not. BK virus can cause pneumonitis, hepatitis, retinitis, and meningoencephalitis. Symptoms include dysuria, urgency, frequency, suprapubic pain and varying degrees of hematuria (Blackard *et al*., 2020).

2.1.5.4 Pathogenesis
Primary infections with BKV and JCV are typically subclinical or linked to mild respiratory illness (Chantziantoniou *et al*., 2016), followed by viral dissemination to the sites of lifelong persistent infection. The major sites of persistence for both BKV and JCV are the cells of the kidney and urinary tract. BKV sequences have been detected at a high frequency in urogenital tissues and fluids including the cervix, vulva, prostate, and semen, and a relatively lower frequency in brain tissues, consistent with its urotheliotropic nature (Zhou *et al*., 2023).

2.1.5.5 Diagnosis
A diagnosis of BKV requires a biopsy but can be suggested or supported by the detection of viral replication in urine or blood. The urine of patients with BKV may show "Decoy cells" which are infected renal tubular epithelial cells with intranuclear basophilic inclusion bodies seen on the Papanicolaou stain (Chantziantoniou *et al*., 2016). BK viral replication can be documented by urine or blood BK viral DNA polymerase chain reaction (PCR) or urine mRNA-PCR. The differential diagnosis for JC virus is HIV-associated encephalopathy and primary CNS lymphoma (Cortese *et al*., 2023).

2.1.5.6 Prevention
Prevention of primary infection can be achieved through large-scale population immunization. The use of specific viral-like particles as a vaccine before the risk of development of polyomavirus diseases may therefore have a protective effect against the disease (Atkinson and Atwood, 2020).

2.1.5.7 Treatment
At present, there is no antiviral therapy specifically licensed for the treatment of either JCV or BKV infections (De Gascun and Carr, 2024). However, the first line of action of BK virus nephropathy is reduction of immunosuppression (Gorriceta *et al*., 2023). Drugs with reported in vitro activity against BK virus such as cidofovir, leflunomide or quinolones have been used in combination with immunosuppression reduction. Patients with JC virus, HIV initiation or optimization of HAART needs to be implemented to decrease viral replication. In non-HIV patients with JC virus infection such as organ transplant patients,

immunosuppression needs to be decreased or stopped (Pietropaolo *et al*., 2018). In inflammatory disease conditions, steroids may be used. Mefloquine, an oral antimalarial drug, is now undergoing clinical trials for JC (Cortese *et al*., 2021).

3. Impacts, Prevention and Control of Waterborne Viral Diseases

3.1 Impact on Public Health

1. Outbreaks: Waterborne viral infections can cause outbreaks in communities, especially in areas with poor sanitation and access to clean water, and high population density (Chen *et al*., 2021; Uba and Okonkwo *et al*. 2025; Okonkwo *et al*., 2026).
2. Health disparities: Poor and marginalized communities are often more affected by waterborne viral infections, as they may not have access to clean water and sanitation (Oghonim, 2023; Orji and Oghonim, 2023; Oghonim *et al.*, 2026a; 2026b).
3. Economic impacts: Outbreaks of waterborne viral infections can have economic impacts, as they can lead to lost productivity and increased healthcare costs (Dokubo and Uba, 2026; Uba and Udaba *et al*. 2026).
4. Chronic conditions: Some waterborne viral infections can cause chronic conditions like hepatitis, which can lead to long-term health problems.
5. Foodborne illnesses: Waterborne viral infections can also cause foodborne illnesses if contaminated water is used to grow or process food.

3.2 Impacts on public health infrastructure and resources in Nigeria

Nigeria's public health system continues to face substantial challenges that significantly affect healthcare delivery, disease prevention, and population health outcomes. As the most populous country in Africa, with an estimated population exceeding 230 million people, Nigeria experiences increasing pressure on its healthcare infrastructure due to rapid population growth, urbanization, emerging infectious diseases, and a rising burden of non-communicable diseases (NCDs). These challenges have profound implications for healthcare resources, workforce capacity, service delivery, and overall public health preparedness.

One of the most significant impacts is the **strain on healthcare infrastructure**. Many public health facilities, particularly in rural and underserved communities, suffer from inadequate equipment, insufficient laboratory capacity, poor maintenance, and limited access to essential medical supplies. According to the Federal Ministry of Health and Social Welfare (2024), many primary healthcare centres operate below optimal standards due to infrastructural deficits and inadequate funding. Consequently, patients often experience delays in diagnosis and treatment, leading to poorer health outcomes and increased disease transmission.

Another major concern is **inadequate healthcare financing**. Nigeria consistently allocates a relatively low proportion of its national budget to health compared to the 15% target established by the Abuja Declaration. The heavy reliance on out-of-pocket expenditure remains a significant barrier to healthcare access, particularly among vulnerable populations. Recent estimates indicate that out-of-pocket spending accounts for more than 60% of total health expenditure, exposing households to catastrophic healthcare costs and limiting utilization of essential health services (World Health Organization [WHO], 2024). This financing gap restricts investments in healthcare infrastructure, medical equipment, pharmaceuticals, and human resources.

The country also faces a persistent **shortage of skilled healthcare professionals**. The migration of doctors, nurses, medical laboratory scientists, pharmacists, and other healthcare workers to developed countries has intensified workforce shortages, a phenomenon commonly referred to as "brain drain." According to the Nigerian Medical Association, thousands of healthcare professionals have emigrated over the past decade in search of better remuneration and working conditions (Adebisi *et al*., 2023). This shortage compromises service delivery, increases patient-to-provider ratios, and places additional pressure on the remaining healthcare workforce.

Frequent outbreaks of infectious diseases continue to burden Nigeria's public health infrastructure. Diseases such as *Lassa Fever*, *Cholera*, *Malaria*, *Tuberculosis*, and *COVID-19* have repeatedly tested the resilience of the healthcare system. Recent cholera outbreaks across several Nigerian states highlighted weaknesses in water, sanitation, hygiene infrastructure, disease surveillance, and emergency response systems (WHO, 2024). Similarly, recurrent Lassa fever outbreaks have underscored the need for improved laboratory networks, surveillance mechanisms, and outbreak preparedness.

The increasing prevalence of **non-communicable diseases (NCDs)** such as hypertension, diabetes mellitus, cardiovascular diseases, and cancer further compounds the pressure on healthcare resources. The epidemiological transition from predominantly infectious diseases to a dual burden of communicable and non-communicable diseases requires greater investments in diagnostic services, specialized healthcare facilities, and long-term disease management programmes (Akinyemi *et al*., 2024).

Nigeria's public health system also remains partially dependent on international donor support for critical programmes related to HIV/AIDS, tuberculosis, malaria control, immunization, maternal health, and child health services. While donor-funded programmes have contributed significantly to disease control efforts, concerns remain regarding sustainability and resilience in the face of declining external funding (United Nations Children's Fund [UNICEF], 2024).

Despite these challenges, recent reforms have demonstrated progress toward strengthening public health infrastructure. Initiatives such as the Basic Health Care Provision Fund (BHCPF), expansion of the National Health Insurance Authority (NHIA), digital health innovations, and investments in primary healthcare revitalization have improved healthcare accessibility and service delivery in some regions (Federal Ministry of Health and Social Welfare, 2024). However, sustained political commitment, increased domestic funding, workforce retention strategies, and infrastructural development remain essential for achieving universal health coverage and strengthening health system resilience.

3.3 Efforts to Prevent and Control Waterborne Viral Diseases

Globally, Organizations like the World Health Organization (WHO) and UNICEF are working to improve access to clean water and sanitation in developing countries, as well as providing vaccines and treatment for waterborne viral infections (Lanrewaju *et al*., 2022).

In Nigeria, the government and local organizations are working to improve sanitation and access to clean water. There are also efforts to educate people about the dangers of waterborne viral infections and how to prevent them. Some efforts by the Nigerian government include, launching of the "Clean Nigeria" in 2018, the use the Toilet campaign, which aims to provide access to toilets and improve sanitation in the country (Uba and Chukwura, 2016; Okoye *et al*., 2016a; 2016b; Dokubo *et al*., 2024; Idu *et al*., 2026a; 2026b). In November 2018, the Nigerian President declared a state of emergency in the Water, Sanitation, and Hygiene (WASH) sector, demonstrating political will at the highest level of government, and launched a national campaign tagged 'Clean Nigeria: Use the Toilet' to jump-start the country's journey towards becoming Open Defecation Free (ODF) by 2025 (WaterAid, 2024).

In 2020, the WHO and other organizations provided support for the response to the hepatitis E outbreak in Nigeria, including providing medical supplies and personnel (WHO, 2023c). In 2021, UNICEF announced that they had reached 4.8 million people in Nigeria with water, sanitation, and hygiene services (UNICEF, 2024).

4. Conclusion

Water-borne viral diseases are spread by viruses that are transferred to humans through contaminated water. Preventing waterborne viral diseases involves ensuring the safety and cleanliness of water sources. This includes implementing proper water treatment and sanitation practices, such as chlorination and filtration, to remove or kill pathogens. Additionally, promoting good hygiene habits like handwashing and proper food handling can help reduce the risk of viral infections transmitted through water. A combined effort of local and global health-based organizations is required to combat the challenges of water-borne viral diseases especially in the developing countries.

References

Adebisi, Y. A., Alaran, A. J., Bolarinwa, O. A., Akande-Sholabi, W., & Lucero-Prisno, D. E. (2023). Migration of healthcare workers from Nigeria: Implications for healthcare delivery and policy responses. *Human Resources for Health*, *21*(1), 1–9.

Adelodun, B., Ajibade, F.O., Ighalo, J.O., Odey, G., Ibrahim, R.G., Kareem, K.Y. (2021). Assessment of socioeconomic inequality based on virus-contaminated water usage in developing countries: a review. *Environmental Research*, **192**:110309

Aggarwal, R. (2011). Clinical presentation of hepatitis E. *Virus Research*, **161**(1):15–22.

Aggarwal, R., and Naik, S. (2009). Epidemiology of hepatitis E: current status. *Journal of Gastroenterology and Hepatology*, **24**(9):1484–1493.

Akinyemi, J. O., Adebowale, A. S., & Bamgboye, E. A. (2024). Rising burden of non-communicable diseases in Nigeria: Implications for healthcare systems and policy. *BMC Public Health, 24*(1), 1–11.

Al Awaidy, S.T., and Khamis, F. (2020). Wild Poliovirus Type 1 in Oman: A re-emerging threat that requires urgent, targeted and strategic preparedness. *Sultan Qaboos University Medical Journal*, **20**(1): e1- e4

Alfred, P.N., Mbachu, I.A.C. and Uba, B.O. (2023). Water Quality Indices and Potability Assessment of Three Streams in Akwa North and South Local Government Areas, Anambra State, Nigeria. *Journal of Applied Sciences and Environmental Management* **27** (2):223 – 228. https://dx.doi.org/10.4314/jasem.v27i2.6.

Alfred, P. N., Mbachu, I. A. C., Uba, B. O.1, Iweriolor, S.N. and Okemadu, O.C. (2025). Bacterial Pathogen Community Profiling of Three Freshwater Bodies in Akwa North and South Local Government Areas, Anambra State, Nigeria. *IPS Journal of Public Health* **5**(3): 302-309. https://doi.org/10.54117/rrrmk019.

Anameze, C.I., Emmy-Egbe, I.O., Anyaegbunam, L.C., Ogomaka, I.J., Uba, B.O., Odumodu, O.A., Ezeigwe, C., Kamalu, N.L., Chukwubude, C.B., Akogu, O., Ezekwueme, E., Emmy-Egbe, C.C., Obiefoka, O.S., Ezenwata, S.I. and Ilechukwu, C.C. (2023). Qualitative and quantitative phytochemical analysis of *Gongronema latifolium* leaf extract. *IPS Journal of Applied Microbiology and Biotechnology* **2** (1): 16 – 19. https://doi.org/10.54117/ijamb.v2i1.10.

Annan, E., Agyei-Tuffour, B., Bensah, Y.D., Konadu, D.S., Yaya, A., Onwona-Agyeman, B., and Nyankson, E. (2018). Application of clay ceramics and nanotechnology in water treatment: a review. *Cogent Engineering*, **5**(1):1476017

Anidu, F.N., Uba, B.O., Ezemba, C.C., Okoye, E.L. and Dokubo, C.U. (2023). Study on optimization, degreasing and destaining potentials of glycophospholipid biosurfactant produced by *Bacillus* anthracis S62A. *Dutse Journal of Pure and Applied Sciences* **9** (1a): 29 – 43. https://dx.doi.org/10.4314/dujopas.v9i1a.4.

Atkinson, A.L., and Atwood, W.J. (2020). Fifty years of JC polyomavirus: A brief overview and remaining questions. *Viruses*, **12**(9): 969

Atmar, R.L., Ramani, S., and Estes, M.K. (2018). Human noroviruses: recent advances in a 50-year history. *Current Opinion in Infectious Diseases*, **31**(5):422-432.

Atmar, R. L. Noroviruses: state of the art. *Food Environ. Virology*, **2**: 117–126 (2010).

Blackard, J. T., Davies, S. M., Laskin, B. L. (2020). BK polyomavirus diversity: Why viral variation matters. *Review in Medical Virology*, **30** (4): e2102

Boothpur, R., and Brennan, D.C. (2010). Human polyomaviruses and diseases with emphasis on clinical BK and JC. *Journal of Clinical Virology*, **47**(4): 306 – 312.

Brown, B., Oberste, M.S., Maher, K., and Pallansch, M.A. (2003). Complete genomic sequencing shows that polioviruses and members of human enterovirus species C are closely related in the noncapsid coding region. *Journal of Virology*, **77**(16):8973-8984

Capece, G., and Gignac. E. (2023). Norovirus. In: StatPearls: StatPearls Publishing. Accessed on 11/5/2024 from: https://www.ncbi.nlm.nih.gov/books/NBK513265/

Center for Disease Control (2024). Norovirus Facts and Stats. Accessed on 11/5/2024 from: https://www.cdc.gov/norovirus/data-research/index.html

Center for Disease Control (2021). Norovirus—Specimen Collection. U.S. Department of Health & Human Services.

Center for Disease Control and Prevention (CDC) (2005). Positive Test Results for Acute Hepatitis A Virus Infection among Persons with No Recent History of Acute Hepatitis—United States, 2002—2004. *Morbidity and Mortality Weekly Report*, **54**:453–456.

Chantziantoniou, N., Joudeh, A. A., Hamed, R. M. A., Al-Abbadi, M. A. (2016). Significance, cytomorphology of decoy cells in polyomavirus-associated nephropathy: Review of clinical, histopathological, and virological correlates with commentary. *Journal of American Society of Cytopathology*, **5**(2): 71–85.

Chen, L., Deng, Y., Dong, S., Wang, H., Li, P., Zhang, H., and Chu, W. (2021). The occurrence and control of waterborne viruses in drinking water treatment: A review. *Chemosphere*, **281**:130728.

Chukwura, E. I., Uba, B. O., Dibua, N. A., Chude, C. O., Okoye, E. C. S., Ubajekwe, C.C., Eleanya, L. C., Agbo, B. C. and Nwajiobi, F. O. (2025). Physicochemical and bacteriological quality assessment of Ogbunike abattoir wastewater Anambra State, Nigeria for irrigation purpose. *Journal of Global Ecology and Environment* **21** (3): 378 – 385. doi.10.56557/jogee/2025/v21i39625.

Cortese, I., Reich, D.S., and Nath, A. (2021). Progressive multifocal leukoencephalopathy and the spectrum of JC virus-related disease. *Nature Review Neurology*, **17**, 37–51.

Costa-Mattioli, M., Monpoeho, S., Nicand, E., Aleman, M.H., Billaudel, S., and Ferré, V. (2002). Quantification and duration of viraemia during Hepatitis A infection as determined by Real-Time RT-PCR. *Journal of Viral Hepatology*, **9**:101–106.

Davlantes, E., Greene, S.A., Tobolowsky, F.A., Biya, O., Wiesen, E., Abebe, F., Weldetsadik, M.B., Eboh, V.A., Chisema, M.N., da Conceição, M. B., Tinuga, F., Bobo, P.M., Chigodo, C.K., Sethy, G., Hellström, J.M., Goundara, A.M., Burny, M.E., Mwale, J.C., Jorba, J., Makua, K.S., Howard, W., Seakamela, L., Okiror, S., Thompson, A., Ali, A., Samba, D., Agbo, C., Kabamba, L., Kazoka, A., Zomahoun, D.L., Manneh, F., Abdelrahim, K., Kamugisha, C., and Umar, A.S. (2023). Update on Wild Poliovirus Type 1 Outbreak - Southeastern Africa, 2021-2022. *Morbidity and Mortality Weekly Report*, **72**(15): 391-397.

De Gascun, C.F., and Carr, M.J. (2013). Human polyomavirus reactivation: disease, pathogenesis and treatment approaches. *Clinical and Developmental Immunology*, **2013**: 373579.

de Graaf, M., Villabruna, N., and Koopmans, M. P. (2017). Capturing norovirus transmission. *Current Opinion in Virology*, **22**: 64–70

Department of Health (2022). Causes and symptoms of waterborne illness. Department of Health, Minnesota, USA. Assessed on 11/5/2024 from: https://www.health.state.mn.us/diseases/waterborne/basics.html#:~:text=Waterborne%20illness%20is%20caused%20by,person%2Dto%2Dperson%20spread.

Dokubo, C. U., Uba B. O., Nnubia, C.P. and Akaun, I.P. (2022a). Evaluation of toxicity and resistant effects of heavy metals and antibiotics on the growth of marine bioluminescent bacteria. *International Journal of Frontline Research in Science and Technology* **01** (02): 030 – 037. https://doi.org/10.56355/ijfrst.2022.1.2.0041.

Dokubo, C. U., Uba B. O. and Nnaji, I. G. (2022b). Combined coagulation and disinfection efficiencies of *Mangifera indica*, *Carica papaya* and solar disinfection on synthetic agro - waste water. *International Journal of Advanced Multidisciplinary Research and Studies* **2** (4):789 - 793. https://www.multiresearchjournal.com/arclist/list-2022.2.4/id-437.

Dokubo, C.U. and Uba, B.O. (2023). Assessment of the decontamination and disinfecting potentials of *Ocimum gratissimum* synthesized silver nanoparticles on water and wastewater samples. *IPS Journal of Public Health* **3** (2): 58 – 65. https://doi.org/10.54117/ijph.v3i2.20.

Dokubo, C.U., Mbachu, I.A.C., Umeaku, C.N. and Uba, B.O. (2024). Isolation, screening and identification of multi – metal resistant fungi isolated from biogas slurry sample. *Tropical Journal of Applied Natural Sciences*, 2 (2): 140 – 159.

Dokubo, C.U. and Uba, B.O. (2026). Green synthesis of Calcium oxide Nanoparticles by Endophytic Fungi for Sustainable Textile and Leather Wastewtare Remediation. *IPS Journal of Applied Microbiology and Biotechnology*, 6(1), 378 - 396. **https://doi.org/10.54117/ijamb.v6i1.14.**

Egurefa, S.O., Orji, M.U. and Uba, B.O. (2020a). Toxic effect of refinery industrial effluent using three toxicity bioassays. *South Asian Journal of Research in Microbiology,* 6 (2): 10 – 23.

Egurefa, S.O., Orji, M.U. and Uba, B.O. (2020b). Toxicological evaluation of two Nigerian refinery effluents using natural biomonitors. *Research & Reviews: A Journal of Toxicology*, 10 (2): 22 – 31.

Ele, E.E., Okoye, E.L., Uba, B.O., Aniekwu, C.C., Iheukwumere, C.M., Obumseli, H. and Okoye, P.A. (2024). Antibacterial effects of phytofabricated silver nanoparticles against some selected bacteria. *International Journal of Research and Innovation in Applied Science* 9 (10): 460 – 467. https://doi.org/10.51584/IJRIAS..

Federal Ministry of Health and Social Welfare. (2024). *Nigeria Health Sector Renewal Investment Initiative: Strategic Blueprint*. Abuja, Nigeria.

Foster, M., Ramachandran, S., and Myatt, K. (2018). Hepatitis A Virus Outbreaks Associated with Drug Use and Homelessness - California, Kentucky, Michigan, and Utah, 2017. *Morbidity Mortality Weekly Reports*, **67**(43):1208–1210

Gall, A.M., Mariñas, B.J., Lu, Y., and Shisler, J.L. (2015). Waterborne viruses: a barrier to safe drinking water. *PLoS Pathogen*, **11**(6): e1004867.

Gaythorpe, K.A.M., Trotter, C.L., and Conlan, A.J.K. (2018). Modelling norovirus transmission and vaccination. *Vaccine*, **36**(37):5565-5571.

Gonzalez, H., Ottervald, J., Nilsson, K.C., Sjögren, N., Miliotis, T., Von Bahr, H., Khademi, M., Eriksson, B., Kjellström, S., Vegvari, A., Harris, R., Marko-Varga, G., Borg, K., Nilsson, J., Laurell, T., Olsson, T., and Franzén, B. (2009). Identification of novel candidate protein biomarkers for the post-polio syndrome - implications for diagnosis, neurodegeneration and neuroinflammation. *Journal of Proteomics*, **71**(6):670-681

Gorriceta, J.H., Otbo, A.L., Uehara, G., and Salas, M.A.P. (2023). BK viral infection: A review of management and treatment. *World Journal of Transplantation*, **13** (6): 309 – 320.

Greene, S.A., Ahmed, J., Datta, S.D., Burns, C.C., Quddus, A., Vertefeuille, J.F., and Wassilak, S.G.F. (2019). Progress Toward Polio Eradication - Worldwide, January 2017-March 2019. *Morbidity and Mortality Weekly Reports*, **68**(20):458-462

Gullón, P., Varela, C., Martínez, E.V., and Gómez-Barroso, D. (2017). Association between meteorological factors and hepatitis A in Spain 2010–2014. *Environment International*, **102**:230–235.

Ibe, C.O., Mbachu, I.A.C. and Uba, B.O. (2023). Analysis and characterization of untreated greywater obtained from Enugu Metropolis. *Tropical Journal of Applied Natural Sciences* 1 (1): 1 – 17. https://tjansonline.org/view-paper.php?id=20.

Ibo, E.M., Umeh, O.R., Uba, B.O. and Egwuatu, P.I. (2020). Bacteriological assessment of some borehole water samples in Mile 50, Abakaliki, Ebonyi State, Nigeria. *Archives of Agriculture and Environmental Science* 5 (2): 179 – 189. https://doi.org/10.26832/24566632.2020.0502015.

Idu, P. N., Chukwura, E. I., Uba, B. O., Okoli, F. A., & Oghonim, P. A. N. (2026a). Assessment of the bacteriological quality of selected surface water resources in Anambra Central Senatorial Zone, Anambra State. *Journal of Public Health, Policy, and Society*, 3(1), 87–100. https://doi.org/10.54117/b8kkjp54.

Idu, P. N., Chukwura, E. I., Okonkwo, I. F., Uba, B. O., & Oghonim, P. A. N. (2026b). Microbial Diversity Metrics: An Insight into the Ecological Status of Different Water Resources in Anambra State Central Senatorial Zone, Nigeria. *IPS Interdisciplinary Journal of Biological Sciences*, 6(1), 257–271. https://doi.org/10.54117/iijbs.v6i1.143.

Jacobsen K.H. (2018). Globalization and the Changing Epidemiology of Hepatitis A Virus. *Cold Spring Harbor Perspective in Medicine*, **8**: a031716.

Karst, S.M. (2010). Pathogenesis of noroviruses, emerging RNA viruses. *Viruses*, **2**(3): 748 - 781

Kim, J.U., Ingiliz, P., Shimakawa, Y., and Lemoine, M. (2021). Improving care of migrants is key for viral hepatitis elimination in Europe. *Bulletin of the World Health Organisation*, **99**(4):280–286

Kirby, A. E., Streby, A. and Moe, C. L. (2016). Vomiting as a symptom and transmission risk in norovirus illness: evidence from human challenge studies. *PLoS One*, **11:** e0143759

Lanrewaju, A.A., Enitan-Folami, A.M., Sabiu, S., Edokpayi, J.N., and Swalaha, F.M. (2022). Global public health implications of human exposure to viral contaminated water. *Frontiers in Microbiology*, 13:1 – 10.

Lhomme, S., Marion, O., Abravanel, F., Izopet, J., and Kamar, N. (2020). Clinical Manifestations, Pathogenesis and Treatment of Hepatitis E Virus Infections. *Journal of Clinical Medicine*, **9**(2):331.

Lowther, J.A., Bosch, A., Butot, S., Ollivier, J., Mäde, D., Rutjes, S.A., Hardouin, G., Lombard, B., In't Veld, P., and Leclercq, A. (2019). Validation of EN ISO Method 15216—Part 1—Quantification of Hepatitis A Virus and Norovirus in Food Matrices. *International Journal of Food Microbiology*, **288**: 82–90.

Mundi, K.S., Okoye, E.L., Uba, B.O., Esimone, C.O. and Attama, A.A. (2013). Evaluation of the antibacterial activity of some commercial disinfectants against methicillin-resistant *Staphylococcus aureus. International Journal of Applied Science and Engineering* 1 (1): 19 – 22. http://dx.doi.org/10.2139/ssrn.3448993.

Mundi, S.K; Okoye, E.L., Uba, B.O., Esimone, C.O, and Attama, A.A. (2014). The combined antibacterial activity of face cleaning agent and *Psidium guajava* leaf extract on methiciliin resistant *Staphylococcus aureus*. *International Journal of Agriculture and Biosciences* 3 (2): 77 – 81. https://www.ijagbio.com/pdf-files/volume-3-no-2-2014/77-81.pdf

Mehndiratta, M.M., Mehndiratta, P., and Pande, R. (2014). Poliomyelitis: historical facts, epidemiology, and current challenges in eradication. *Neurohospitalist*, **4**(4):223-229.

McIntosh, E.D.G. (2018). Healthcare-associated infections: potential for prevention through vaccination. *Therapeutic Advances in Vaccines and Immunotherapy*, **6**(1):19-27

McKee, A.M., and Cruz, M.A. (2021). Microbial and viral indicators of pathogens and human health risks from recreational exposure to waters impaired by fecal contamination. *Journal of Sustainable Water Built Environment*, **7**(2):03121001

Migueres, M., Lhomme, S., and Izopet, J. (2021). Hepatitis A: Epidemiology, High-Risk Groups, Prevention and Research on Antiviral Treatment. *Viruses*,**13**(10):1900

Nelson, N.P., Weng, M.K., Hofmeister, M.G., Moore, K.L., Doshani, M., Kamili, S., Koneru, A., Haber, P., Hagan, L., and Romero, J.R. (2020). Prevention of Hepatitis A Virus Infection in the United States: Recommendations of the Advisory Committee on Immunization Practices, 2020. *Morbidity and Mortality Weekly Recommendation Reports*; **69**: 1–38.

Pietropaolo, V., Prezioso, C., Bagnato, F., and Antonelli, G. (2018). John Cunningham virus: an overview on biology and disease of the etiological agent of the progressive multifocal leukoencephalopathy. *New Microbiology*, **41**, 179–186.

Prezioso, C., Van Ghelue, M., Pietropaolo, V., and Moens, U. (2021). Detection of Quebec polyomavirus DNA in samples from different patient groups. *Microorganisms,* **9** (5):1082.

Ramírez-Castillo, F.Y., Loera-Muro, A., Jacques, M., Garneau, P., Avelar-González, F.J., Harel, J., and Guerrero-Barrera, A.L. (2015). Waterborne pathogens: detection methods and challenges. *Pathogens*, 4(2):307-334.

Rockx, B., de Wit, M., Vennema, H., Vinje, J., de Bruin, E., Duynhoven, Y.V., and Koopmans, M. (2002). Natural history of human calicivirus infection: a prospective cohort study. *Clinical Infectious Diseases,* **35**, 246–253.

Magana-Arachchi, D.N., and Wanigatunge, R.P. (2020). Ubiquitous waterborne pathogens. In: *Waterborne Pathogens*, Butterworth-Heinemann Publishers. pp 15–42.

Nwigwe, V.N. and Uba, B.O. (2022). Role of electrochemically active bacteria in the treatment of piggery and poultry wastewaters from Umuagwo in Ohaji Egbema Local Government Area of Imo State, Nigeria. *Journal Applied Science and Environmental Management* 26 (12): 2085 – 2093. https://dx.doi.org/10.4314/jasem.v26i12.24.

Nwigwe, V. N., Nwigwe, H. C., Okereke, J. N., Uba, B.O. and Dokubo, C.U. (2023). Potential of agro-based industrial wastewater as an alternative substrate for bioelectricity. *Animal Research International* 20 (1): 4741 – 4747.https://www.ajol.info/index.php/ari/article/view/246974.

Obiefoka, S.O., Emmy-Egbe, I.O., Anyaegbunam, L.C., Uba, B.O., Anameze, C.I., Ogoamaka, I.J., Kamala, N.L., Ezeigwe, C., Akaogu, O., Odumodu, O.A., Emmy-Egbe, C.C., Ezenwata, O.S. and Chukwubude, C.B. (2023). The Prevalence of Lymphatic Filariasis Infection among Primary School Children (5-9 Years) of Infected Adults in Ihiala Local Government Area of Anambra State, Nigeria. *IPS Journal of Public Health*, 3 (2): 66 - 72.

Obiefuna, O. H., Nzekwe, C. M., Onuorah, S. C., Uba, B. O., Ubajekwe, C. C., Okey-Ndeche, N. F., and Ike, V. E. (2025). Assessment of the seasonal impact on physicochemical quality of borehole water samples in Emene, Enugu State, Nigeria. *IPS Journal of Public Health* 5 (4): 422 – 430. https://doi.org/10.54117/8rr3ms81.

Obiefuna, O. H., Onwuofor, E. C., Nduka, A. C., Uba, B. O., Ebenebe, I. N., Ngozika, F. O. N., Mere, C.A. and Egbe, P.A. (2026). Molecular Analysis and *In Vitro*Pathogenicity Evaluation of Bacteria Isolated from Frozen Chicken. *IPS Journal of Nutrition and Food Science,* 6(1): 755 - 763.

Oghonim, P. A. N. (2023). Evaluation of the bacteriological characteristics of selected borehole water samples in Agbor, Delta State, Nigeria. *Newport International Journal of Scientific and Experimental Sciences (NIJSES), 3*(3), 168 – 185.

Oghonim, P. AN., Uba, B. O., Afulukwe, S.C., Dokubo, C.U., Okongwu, D.J., Mere, C.A. and Anaebonam, E.C. (2026a). Molecular Identification, Phylogenetic Analysis, and Antibiotic Susceptibility Profiles of Bacteria Isolated from Borehole Water across Seasonal Variations. *Interdisciplinary Journal of Biological Sciences,* 6(2): 272 - 283.

Oghonim, P. AN., Onuorah, S. C., Onyima, C. S., Idu, P. N., Uba, B. O., Onyekpeze, C. E., Agbakhamon, E., Alari, E. J., Osunde, G., & Ottah, F. (2026b). Public health risk assessment of heavy metal contamination in abattoir wastewater-irrigated soil and edible crops in Agbor, Delta State, Nigeria. *INOSR Applied Sciences, 14*(1): 9 – 17.

Okafor, C. A., Uba, B.O. and Dokubo, C.U. (2023). Application of myco-fabricated silver nanoparticle in the adsorption malachite green and trypan blue from aqueous solution. *Nigerian Journal of Life Sciences* 12 (2): 8 – 15. https://doi.org/10.52417/njls.v12i2.354.

Okolo, O.C., Uba, B. O. and Ike, V.O. (2025). Influence of untreated noodle wastewater on physicochemical, enzymatic and bacteriological dynamics of soil. (2025). *Journal of Pollution Monitoring, Evaluation Studies and Control* 4 (2): 110 –119. https://doi.org/10.54117/jpmesc.v4i2.20.2025.

Okonkwo, O. P., Uba, B. O., Ifemeje, J. C., Ozochi, C. A., Okongwu, D. J. & Anaebonam, E. C. (2026). Green Synthesis of Silver Nanoparticles from Aqueous Seed Extract of C. papaya and its Application in Surface Water Resources Decontamination. *IPS Journal of Plant, Animal, and Environmental Sciences*, 2(1): 22–31. https://doi.org/10.54117/ijpae.v2i1.121.

Okoye, E.L., Obiweluozor, C.J., Uba, B.O. and Odunukwe, F.N. (2016a). Epidemiological survey of tonsillitis caused by *Streptococcus pyogenes* among children in Awka Metropolis (A case study of hospitals in Awka Community, Anambra State). *IOSR Journal of Pharmacy and Biological Sciences,* 11 (3): 54 – 58.

Okoye, E.L., Ozumba, A.I., Uba, B.O. and Odunukwe, F.N. (2016b). Prevalence of Hepatitis B Virus among immunocompromised individuals attending Nnamdi Azikiwe University Teaching Hospital (NAUTH), Nnewi. *Journal of Pharmaceutical and Allied Sciences,* 13 (2):2407 - 2413.

Okoye, C. P., Mbachu, I. A. C., Uba, B. O., Okongwu, D. J., Mere, C. A., Anaebonam, E. C. and Dokubo, C. U. (2026). Chemical Oxygen Demand Reduction Potential of Halotolerant Bacterial Consortia in Saline Wastewater Treatment System. *International Journal of Global Trends and Research*, 3 (2): 199 - 203.

Okpalaunegbu, C.A., Chinweuba, A.J., Ojiako, E.N., Uba, B.O. and Okafoanyali, J.O. (2025). Physicochemical properties and heavy metal analysis of sewage and leachate wastewater collected from the Sewage Tank at the University of Nigeria, Nsukka and the First Market Municipal Dumpsite, Ifite-Awka, Anambra State. Journal of Global Ecology and Environment 21 (3): 320 – 332. https://doi.org/10.56557/jogee/2025/v21i39583

Orji, M. U., & Oghonim, P. A. N. (2023). Evaluation of the average physical parameters of selected borehole water samples in Agbor, Delta State, Nigeria. *IDOSR Journal of Scientific Research, 8*(3), 125–138.

Uba, B.O., Okoye, E.L. and Chukwura, E.I. (2016). Bioremediating potentials of marine mercury-resistant bacteria on polyaromatic hydrocarbons components of Bonny light crude oil. *Journal of Advances in Biology and Biotechnology*, 7 (4): 1- 12.

Uba, B. O., Okoye, E. L., Ekwueme, C., Azubike, T. C. and Ugoma, J.C. (2017). Heavy metals and antibiotics resistance pattern of bacteria isolated from brewery and plastic industries effluent waste. *African Journal of Education, Sciences and Technology,* 3(3): 43 – 50.

Uba, B.O., Okoye, E.L., Anyichie, J.C., Dokubo, C.U. and Ugwuoji, E.T. (2024). Synthesis, characterization and application of biogenic silver nanoparticles as antibacterial and antifungal agents. *Journal of Advances in Microbiology* 24 (3): 65 – 78. https://doi.org/10.9734/JAMB/2024/v24i3809.

Uba, B .O., Alfred, P. N., Ukpai, E. G., Ike, V. E. & Chikwendu, J. C. (2025). Diversity Of the Bacterial Communities Of Three Selected Streams In Anambra State, Nigeria. *Open Journals of Environmental Research*, 6 (2): 59 – 72. DOI: https://doi.org/10.52417/ojer.v6i2.453.

Uba, B.O. and Okonkwo, O.P. (2025). Surface water treatment potentials of silver nanoparticles biosynthesized from *Moringa oleifera* seed extract. *African Journal of Health, Safety and Environment*, 6(2): 01 - 18. https://doi.org/10.52417/ajhse.v6i2.622 .

Uba, B. O. and Udaba, P.I. (2026). Evaluation of the Production of Biosurfactant by Yeast Strains Isolated from Fruit Pastes and their Biodegradative Potential on Waste Engine Oil. *Journal of Pollution Monitoring, Evaluation Studies and Control*, 5 (1): 147 - 157. https://doi.org/10.54117/ejmptp50.

Uba, B. O., Okonkwo, O. P., Idigo, M. A., Igiri, V.C., Okongwu, D. J., Okemadu, O.C. & Anaebonam, E. C. (2026a). Disinfecting Potentials and Eco-Safety Evaluation of Nano-treated Surface Water Resources by Biogenic Silver Nanoparticles Using Bacterial and Phytotoxicity Indices. (2026). *African Journal of Applied Research & Sustainable Development*, 4(1): 47-58. https://doi.org/10.54117/j2qae873.

Uba, B. O., Udaba, P.I., Dibua,N.A., Ubajekwe,C.C., Igiri,V.C.,Okongwu, D. J., & Anaebonam, E. C. (2026b). Toxicity and Safety Evaluation of Glycolipid Biosurfactant Produced by Yeast Strains Isolated from Fruit Pastes. *IPS Journal of Toxicology*, 4(1): 100 - 109. https://doi.org/10.54117/axm1gf40.

Uba, B.O**.,** Dokubo, C.U., Okongwu, D.J., Okemadu, O.C., Mere, C.A., Anaebonam, E.C., Oghonim, P. AN., & Agbata, E.F. (2026c). Potentials of *Aspergillus terreus* and Wistar Mice Bioassays as Tools for Monitoring the Environmental Health Concern of E-Waste Disposal. *Health Science Research International*, 3 (1): 82 - 92. https://doi.org/10.54117/hsri.v3i1.69.

Ubani, O., Obiefuna, G.O., Uba, B.O., Dokubo, C.U., Mere, C. A. and Akaun, I.P. (2024a). Kinetic modelling and half-life study on bioremediation of diesel oil contaminated soil and water using nano - remediation strategy: kinetic modelling and half-life study on bioremediation of diesel oil. *Multidisciplinary Science Journal* **7**: e2025182. https://doi.org/10.31893/multiscience.2025182.

Ubani, O., Uba, B.O**.,** Modise, S. J., Okoye, E. L., Omeazu, S. C., Ndibe, C.R., Umeh, O. R. and Dokubo, C. U. (2024b). Responses of *Selenastrum capricornutum, Eisenia fetida, Brassica nigra* and *Sorghum bicolor* to spent phone battery toxicity. *Multidisciplinary Science Journal*, 6 (7): 2024107 - 2024107.

Ubani, O., Uba, B. O., Modise, S. J., Egurefa, S. O., Orji, M. U. and Dokubo, C. U. (2025). A characterization and evaluation of the ecotoxicity of petroleum refinery effluents using a battery of bioassays. *Multidisciplinary Science Journal* 8 (3): 2026159. https://doi.org/10.31893/multiscience.2026159

Umeh, O.R., Chukwura, E.I., Ibo, E.M. and Uba, B.O. (2020). Evaluation of physicochemical, bacteriological and parasitological quality of selected well water samples in Awka and its environment, Anambra State, Nigeria. *Archives of Agriculture and Environmental Science* 5 (2): 73 – 88. https://doi.org/10.26832/24566632.2020.050201.

Umeh, O.R., Chukwura, E.I., Okoye, E.L., Ibo, E.M., Egwuatu, P. I. and Uba, B.O. (2021). Phytochemical Screening and Antibacterial Evaluation of Conventional Antibiotics, Garlic and Ginger on Isolates from Fish Pond Water Samples in Awka, Anambra State, Nigeria. *Journal of Pharmaceutical Research International* 33(30B): 118-132. https://doi.org/10.9734/jpri/2021/v33i30B31646.

United Nations Children's Fund. (2024). *Nigeria Health Budget and Public Financing Review*. New York: UNICEF.

United Nations International Childrens Emergency Fund (2024). Water, Sanitation and Hygiene. Accessed on 11/5/2024 from: https://www.unicef.org/nigeria/water-sanitation-and-hygiene.

Wang, X., Ren, J., Gao, Q., Hu, Z., Sun, Y., Li, X., Rowlands, D.J., Yin, W., Wang, J., and Stuart, D.I. (2015). Hepatitis A Virus and the Origins of Picornaviruses. *Nature,* **517**:85–88.

WaterAid (2024). Clean Nigeria Campaign. Accessed on 11/5/2024 from: https://www.wateraid.org/ng/get-involved/clean-nigeria-campaign#:~:text=In%20November%202018%2C%20the%20Nigerian,country's%20journey%20towards%20becoming%20Open

Wedemeyer, H., Pischke, S., and Manns, M.P. (2012). Pathogenesis and treatment of hepatitis E virus infection. *Gastroenterology*,**142**(6):1388-1397

Wolbert, J.G., Rajnik, M., and Higginbotham, K. (2024). Poliomyelitis.. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; Accessed from: https://www.ncbi.nlm.nih.gov/books/NBK558944/

World Health Organization. (2024). *Nigeria Health System Profile and Universal Health Coverage Progress Report*. Geneva, Switzerland: World Health Organization.

World Health Organization. (2024). *Cholera and Lassa Fever Situation Reports for Nigeria*. Geneva, Switzerland: World Health Organization.

World Health Organization (2023a). Hepatitis A. Accessed on 11/5/2024 from: https://www.who.int/news-room/fact-sheets/detail/hepatitis-a.

World Health Organization (2023b). Hepatitis E. Accessed on 11/5/2024 from: https://www.who.int/news-room/fact-sheets/detail/hepatitis-e

World Health Organization (2023c). Poliomyelitis. Accessed on 11/5/2024 from: https://www.who.int/news-room/fact-sheets/detail/poliomyelitis

World Health Organization (2022) Guidelines for drinking-water quality: Fourth edition incorporating the first and second addenda (4th ed + 1st add + 2nd add). World Health Organization. Accessed on 11/5/2024 from: https://apps.who.int/iris/handle/10665/352532

World Health Organization (2021). Polio eradication strategy 2022-2026: delivering on a promise. Accessed on 11/5/2024 from: https://polioeradication.org/wp-content/uploads/2021/10/9789240031937-eng.pdf

World Health Organization (2020) State of the world's sanitation: an urgent call to transform sanitation for better health, environments, economies and societies

World Health Organization . *WHO Immunological Basis for Immunization Series, Module 18: Hepatitis A Update.* WHO; Geneva, Switzerland: 2019.

World Health Organization (2016). Polio vaccines: WHO position paper. *Weekly Epidemiological Records*, 91(12):145–168

Yekta, R., Vahid-Dastjerdi, L., Norouzbeigi, S., and Mortazavian, A.M. (2021). Food products as potential carriers of SARS-CoV-2. *Food Control*, **123**:107754

Zeng, D.Y., Li, J.M., Lin, S., Dong, X., You, J., Xing, Q.Q., Ren, Y.D., Chen, W.M., Cai, Y.Y., and Fang, K. (2021). Global Burden of Acute Viral Hepatitis and Its Association with Socioeconomic Development Status, 1990–2019. *Journal of Hepatology,* **2021**: S0168827821003007.

Zhou, X., Zhu, C., and Li, H. (2023). BK polyomavirus: latency, reactivation, diseases and tumorigenesis. *Frontiers in Cell Infection and Microbiology*, **13**: 1263983