EFFECTIVENESS AND OPERATIONAL CHALLENGES OF ENVIRONMENTAL SURVEILLANCE SYSTEMS FOR POLIO ERADICATION IN NIGERIA

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the Study

Poliomyelitis is an infectious disease caused by the poliovirus that predominantly affects children under the age of 15 years (WHO, 2000; Baguune et al., 2024). The clinical outcomes vary from mild, non-specific illness to severe flaccid paralysis that can result in permanent disability (WHO, 2009; Baguune et al., 2024). Even in the absence of visible symptoms, poliovirus can replicate in the para-intestinal submucosal lymphatic tissue for weeks to months (WHO, 2004; Baguune et al., 2024). The Global Polio Eradication Initiative (GPEI), launched in 1988, has led to a reduction in global polio cases by more than 99% (CDC, 2011; Baguune et al., 2024). Since the withdrawal of type 2 and type 3 wild polioviruses in 1999 and 2012 respectively, wild poliovirus type 1 and vaccine-derived polioviruses (VDPVs) remain the main threats to eradication (Diop et al., 2017). VDPVs emerge when weakened strains of the oral polio vaccine circulate for extended periods in under-immunized populations or replicate in immunodeficient individuals, eventually regaining neurovirulence.

Nigeria historically bore the largest burden of polio cases in sub-Saharan Africa (Diop et al., 2017). The country reported its last case of wild poliovirus in 2016, and the African continent was certified free of wild poliovirus thereafter (Diop et al., 2017). Ghana achieved a similar milestone after detecting its last case in 2008 and was declared polio-free in 2015 (Odoom et al., 2014; Baguune et al., 2024). However, the emergence of circulating vaccine-derived poliovirus type 2 (cVDPV2) has become a major challenge to the eradication process (Odoom et al., 2014). By August 2020, 323 cases of cVDPV2 and 84 positive environmental samples had been documented across Africa (GPEI, 2025). Ghana, for instance, recorded its first cVDPV2-positive environmental sample in June 2019 and its first human case in August 2019, with 30 confirmed cases reported by the end of 2020 (GPEI, 2025).

Polio surveillance remains central to eradication efforts. Acute Flaccid Paralysis (AFP) surveillance is considered the gold standard for detecting poliovirus. An AFP case is defined as any child under 15 years with sudden onset of paralysis or weakness in the limbs, or any person at any age in whom poliomyelitis is clinically suspected (Hamisu et al., 2022). AFP surveillance is crucial for confirming polio cases, monitoring outbreaks, and certifying the absence of wild poliovirus circulation (Bassioni et al., 2003; Baguune et al., 2024). However, AFP captures only a fraction of infections since approximately one in every thousand poliovirus infections leads to paralysis, leaving many asymptomatic infections undetected (Kelly et al., 2006; Baguune et al., 2024). This silent circulation poses a risk of continued transmission.

Because poliovirus is excreted in stool for several weeks, it can be identified in sewage or wastewater contaminated with human fecal matter (Odoom et al., 2017). Environmental Surveillance (ES) has therefore been adopted to complement AFP surveillance. ES provides a non-invasive approach to detect poliovirus circulation in communities, regardless of whether individuals develop symptoms (WHO, 2003; Baguune et al., 2024). The Global Polio Eradication Initiative expanded the use of ES between 2013 and 2018, and by 2018, more than 45 countries had introduced ES as part of their national polio surveillance systems (Odoom et al., 2014; GPEI, 2025). Countries such as Nigeria, Kenya, South Africa, Senegal, Cameroon, Madagascar, and Ghana have implemented ES in high-risk areas to supplement AFP surveillance (Weldegebriel et al., 2015; Muluh et al., 2016; Baguune et al., 2024).

In practice, ES involves collecting sewage or wastewater samples from selected catchment areas and testing them for polioviruses and other enteroviruses (WHO, 2003; WHO 2025). Its sensitivity depends on the sewage network, site selection, sample handling, and laboratory processes (Diop et al., 2017; Odoom et al., 2017). When effectively implemented, ES can detect outbreaks earlier than AFP surveillance and guide public health interventions (GPEI, 2025). For instance, findings from ES in Egypt in the early 2000s triggered intensified immunization campaigns and strengthened AFP surveillance (GPEI, 2025). In Nigeria, ES has contributed to identifying circulating vaccine-derived polioviruses and guided targeted vaccination campaigns (Weldegebriel et al., 2015; Muluh et al., 2016).

Despite its promise, ES faces challenges in many African countries. Informal drainage systems, poorly documented catchment populations, and limited laboratory capacity hinder optimal sensitivity (Westmoreland et al., 2021). Nonetheless, ES remains a crucial tool in the final phase of eradication, particularly in settings where AFP surveillance alone cannot reliably detect silent transmission. This study therefore focuses on assessing the effectiveness and operational challenges of environmental surveillance for poliovirus in Nigeria.

## 1.2 Statement of the Problem

Despite the progress made under the Global Polio Eradication Initiative, poliovirus continues to pose a significant threat to public health in Nigeria. The country’s certification as free of wild poliovirus in 2020 was a major milestone (Diop et al., 2017). However, the continued circulation of type 2 vaccine-derived polioviruses (cVDPV2) underscores the fragility of these gains (Odoom et al., 2014; GPEI, 2025). Between 2019 and 2022, Nigeria reported multiple outbreaks of cVDPV2, making it one of the highest-burden countries globally (GPEI, 2025). These outbreaks reveal that silent transmission persists in communities, particularly in underserved and high-risk areas where routine immunization coverage remains suboptimal. Surveillance remains the backbone of polio eradication. Acute Flaccid Paralysis (AFP) surveillance, while still considered the gold standard, captures only the small fraction of infections that manifest with paralysis (Kelly et al., 2009; Baguune et al., 2024). This limitation creates a critical gap, as the majority of infections remain asymptomatic and undetected. Environmental Surveillance (ES) was introduced to bridge this gap, as it can identify poliovirus excreted in stool and present in sewage even when no AFP cases are reported (Odoom et al., 2017). In Nigeria, ES has been credited with early detection of poliovirus and has informed targeted immunization responses (Weldegebriel et al., 2015; Muluh et al., 2016)

Yet, important questions remain unanswered. Despite its potential, the effectiveness of ES in Nigeria is constrained by operational challenges such as weak sewage infrastructure, poor site representativeness, inconsistent sample collection, and limited laboratory capacity (Westmoreland et al., 2001; Odoom et al., 2017). The persistence of poliovirus transmission despite ES expansion raises concerns about whether the system is sufficiently sensitive and sustainable. Furthermore, while AFP and ES are designed to complement each other, there is limited evidence comparing their relative performance in Nigeria’s high-risk states. Without such evaluation, it is difficult to determine the extent to which ES contributes to early detection and outbreak control in the Nigerian context. The critical gap, therefore, lies in the lack of systematic assessment of the effectiveness and operational challenges of environmental surveillance for polio eradication in Nigeria. Understanding this is essential not only for interrupting cVDPV2 transmission but also for sustaining Nigeria’s polio-free certification. This study addresses this gap by examining the contribution of ES to poliovirus detection, comparing it with AFP surveillance and identifying operational challenges, of surveillance systems in Nigeria.

## 1.3 Justification of the Study

Nigeria’s certification as free of wild poliovirus in 2020 was a milestone for Africa, yet outbreaks of circulating vaccine-derived poliovirus type 2 (cVDPV2) continue to undermine progress (Diop et al., 2017; Odoom et al., 2014; GPEI, 2025). This persistence reflects weaknesses in detection systems and highlights the need for closer scrutiny of surveillance approaches. Acute Flaccid Paralysis (AFP) surveillance has historically driven case detection but cannot capture the vast majority of infections that remain asymptomatic (Kelly et al., 2006; Odoom et al., 2017). Environmental Surveillance (ES) was adopted to bridge this gap by testing sewage for polioviruses excreted in stool (Odoom et al., 2017). Its application in Nigeria has shown that it can reveal circulation even in the absence of AFP cases, providing a valuable signal for vaccination campaigns (Baguune et al., 2024). Yet, the Nigerian context presents unique operational difficulties. Unstructured sewage networks, uncertain catchment populations, and resource constraints reduce the sensitivity of the system (Odoom et al., 2017). Delays in sample transport and limited laboratory capacity further restrict timely detection. The recurrence of cVDPV2 despite the expansion of ES raises questions about how well the system is functioning on the ground (GPEI, 2025).

This study is justified for three reasons. Academically, it fills a gap in the literature by assessing the performance of ES in Nigeria, a country that remains central to global eradication goals (Hamisu et al., 2022). Programmatically, it documents the challenges of running ES in settings with weak infrastructure, where theory and implementation often diverge (Odoom et al., 2017). Policy-wise, the findings will support Nigeria and its partners in refining strategies for surveillance, which is a priority in the Global Polio Eradication Initiative’s endgame strategy.

## 1.4 Aims and Objectives

## 1.4.1 Aims

The aim of this study is to assess the effectiveness and operational challenges of environmental surveillance systems on polio eradication in Nigeria.

## 1.4.2 Specific Objectives

The specific objectives of the study are to:

1. Evaluate the contribution of environmental surveillance to the early detection of poliovirus in Nigeria.
2. Compare environmental surveillance with AFP surveillance in selected high-risk states.
3. Identify the operational challenges affecting environmental surveillance implementation.
4. Recommend strategies to improve polio surveillance effectiveness in Nigeria.

## 1.5 Research Questions

1. How effective is environmental surveillance in detecting poliovirus circulation in Nigeria?
2. How does environmental surveillance compare with AFP surveillance regarding sensitivity and coverage?
3. What operational challenges hinder environmental surveillance in Nigeria?

## 1.6 Research Hypothesis

H0: Environmental surveillance does not significantly improve poliovirus detection compared to AFP surveillance alone.

H1: Environmental surveillance significantly improves poliovirus detection compared to AFP surveillance alone.

## 1.7 Scope of the Study

This study is focused on assessing the effectiveness and operational challenges of environmental surveillance for poliovirus eradication in Nigeria. The research is limited to twenty-one states where structured questionnaires were administered: Bauchi, Kogi, Niger, Jigawa, Rivers, Anambra, Oyo, Ogun, Abia, Delta, Osun, Kwara, Katsina, Sokoto, Yobe, Kebbi, Zamfara, Gombe, Kaduna, Kano, and Borno. These states were selected because they are high-risk areas for poliovirus circulation, regions with varying levels of surveillance infrastructure, and states with recent histories of circulating vaccine-derived poliovirus detections. The study examines the role of environmental surveillance in early detection of poliovirus, its comparison with Acute Flaccid Paralysis (AFP) surveillance, and the operational challenges influencing its implementation. Respondents include stakeholders directly involved in polio surveillance activities such as state surveillance officers, environmental health officers, and laboratory personnel. The analysis is restricted to polio surveillance and does not extend to other aspects of immunization programs or surveillance systems for other diseases.

## 1.8 Operational Terms and Definitions

1. **Poliomyelitis (Polio):** A viral disease-causing muscle paralysis, primarily affecting children under five.
2. **Environmental Surveillance (ES):** Testing of sewage and wastewater samples to detect poliovirus circulation.
3. **Acute Flaccid Paralysis (AFP) Surveillance:** Monitoring of sudden onset paralysis cases to detect poliovirus infection.

**CHAPTER TWO**

**LITERATURE REVIEW**

This chapter detailed the relevant literatures review on the study which is to assess the effectiveness and operational challenges of environmental surveillance systems on polio eradication in Nigeria. The chapter includes the theoretical, conceptual and empirical review. The theoretical framework detailed the diseases surveillance theory in surveillance review while the conceptual review addresses the global efforts to eradicate poliovirus, surveillance approaches for poliovirus. The empirical review detailed the contribution of environmental surveillance to early detection of poliovirus, and comparison of environmental surveillance and AFP surveillance and operational challenges.

**2.1 Theoretical Framework**

**2.1.1. Disease Surveillance Theory (DST)**

Disease Surveillance Theory (DST) is a framework that explains how diseases are systematically detected, monitored, and controlled using structured public health systems (McNabb et al., 2002; Gomes et al., 2022). It emphasizes that outbreaks follow a predictable sequence and moves from origin and transmission to detection and institutional response. Surveillance functions as the critical mechanism that interrupts this cycle before widespread harm occurs. The theory builds on the principles introduced by Alexander D. Langmuir in the 1960s. who is widely recognized as the father of modern disease surveillance, described surveillance as:

“*The continued watchfulness over the distribution and trends of incidence through the systematic collection, consolidation, and evaluation of morbidity and mortality reports and other relevant data (Langmuir, 1963)”.*

**2.1.1.2 Application of DST in this study**

The first stage is the origin of infection. Pathogens which are transmitted from animals, or anthropogenic arises within human populations. Most times, zoonotic diseases cross into humans through contact with wildlife or food sources, while anthropogenic origins spread through human-to-human transmission or hereditary traits. In addition, circulating vaccine-derived poliovirus type 2 (cVDPV2) has been repeatedly isolated in sewage systems even in areas with no acute flaccid paralysis (AFP) cases reported. This pattern points to reservoirs maintained in less immunized populations and shaped by gaps in sanitation interventions (Kalkowska et al., 2020).

The second stage involves transmission within populations. Infections spread through contact with body fluids, aerosols, contaminated food or water, and close interaction. Silent transmission, where carriers remain asymptomatic, is a defining feature. This hidden spread sustains outbreaks such as poliovirus, where circulation continues in environmental reservoirs without visible cases. Environmental surveillance (ES) has shown viral presence in sewage despite the absence of paralytic cases. A study of ES sites in Kano and Sokoto demonstrated that enterovirus isolation was more likely in urban catchments with high density and poor waste management (Hamisu et al., 2022). This shows how silent transmission sustains outbreaks.

The third stage is detection through symptomatic cases. Individuals report illness to local health facilities, which act as the frontline of surveillance. Initial case investigations may trigger alerts when clusters suggest a shared source. At this level, routine surveillance data provide the evidence for public health action, as seen with integrated disease surveillance systems across Africa (Muyembe et al., 2024). Between 2012 and 2015, ES in Nigeria detected 97 cVDPV2 and 14 wild poliovirus isolates, while AFP surveillance alone would have missed several events (Abdullalhi et al., 2015). Evidence from Kano also demonstrated that sewage monitoring provided early warning signals months before clinical cases appeared, confirming ES as a more sensitive tool in certain areas (Kalkowska et al., 2020).

The fourth stage is institutional response. Public health authorities and epidemiologists expand investigations through laboratory analysis, contact tracing, and systematic analysis. Surveillance helps in strengthening this phase by identifying unusual signals that routine systems (AFP) may miss. This offer early insight into changes in host species, transmission settings, or viral persistence (McKnight et al., 2024). Especially Sensitivity in operational layer. Sensitivity depends on site selection, sampling frequency, and laboratory capacity (Impalli et al., 2025). Empirical work has shown that the quality of sample processing and the geographical distribution of ES sites determine how quickly outbreaks are recognized and thus addressed (Lickness et al., 2020). Insecurity in northern states further disrupted timely response and exposes gaps in implementation despite strong detection capacity (Akinola et al., 2021). These challenges reflect the third objective of identifying barriers to effective ES.

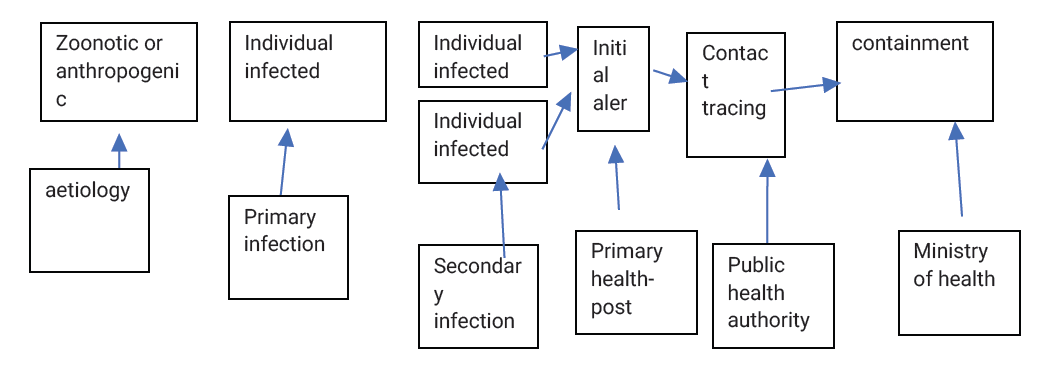


Figure 1: Public health surveillance theory framework (Dzirasah et al., 2024)

The fifth stage involves escalation to national and international levels. Ministries of health mobilize resources, establish containment policies, and coordinate cross-border actions where necessary. Evidence shows that this stage is shaped not only by institutional capacity but also by community participation. Informal actors, such as traditional healers, have been pivotal in detecting and reporting suspected cases, extending the reach of formal systems (Kenu et al., 2024). Nigeria expanded ES to more states after initial gaps were revealed, and modeling has shown that this scale-up directly improved sensitivity to detect poliovirus circulation (Hovi et al., 2012). At national level, ES data have guided targeted immunization campaigns and informed the Global Polio Eradication Initiative’s risk assessments (Hamisu et al., 2022).

These stages form a cycle that explains how surveillance functions in practice. In Nigeria, the persistence of circulating vaccine-derived poliovirus type 2 highlights failures in detecting and interrupting silent transmission between the second and third stages. Environmental surveillance and acute flaccid paralysis surveillance operate within this framework as mechanisms to identify pathogens early, trigger institutional responses, and prevent escalation into larger epidemics.

**2.2 Conceptual Review**

**2.2.1 Poliovirus and Global Eradication Efforts**

Poliovirus is a small RNA virus from the Picornaviridae family. It has stayed at the center of global eradication campaigns because it leaves children with paralysis that never heals and sometimes takes their lives (Thompson & Badizadegan, 2024). The Global Polio Eradication Initiative (GPEI) began in 1988 with a clear mission to eradicate polio. Since then, case numbers have collapsed worldwide. Not to zero. Not yet. However, between 2001 and 2023, reported cases fell sharply. WPV2 disappeared in 1999. WPV3 followed in 2012. But WPV1 refuses to vanish, this is still present in Afghanistan and Pakistan. These two countries remain the last endemic reservoirs. A different threat rose in their place which is circulating vaccine-derived polioviruses (cVDPVs). Since 2018, type 2 outbreaks have spread across continents. By 2021, cVDPV1 cases were higher than WPV1. That changed the map of concern (Badizadegan et al., 2022). The tools against polio also shifted. At first, the oral polio vaccine (OPV) was the weapon of choice. Cheap. Easy to swallow. Strong mucosal immunity. Transmission blocked at the source (Tebbens et al., 2002; Tebbens et al., 2017). But OPV carried risks. Vaccine-associated paralytic polio. And worse, cVDPVs. The solution in developed countries was to turn to inactivated polio vaccine (IPV). Elsewhere, OPV stayed in use and this is supported by supplementary campaigns (Hamisu et al., 2022).

GPEI laid out six phases of strategy. The early years which is 1988 to 2000 pushed for full eradication by the millennium. Routine immunization. Mass campaigns. The payoff was regional: the Americas certified polio-free in 1994, the Western Pacific in 2000, Europe in 2002. Later plans looked harder at OPV risks. They called for new vaccines and the gradual pullback of OPV. In 2016, the world shifted from tOPV to bOPV. A landmark. But after that, cVDPV2 cases exploded. More than 3,300 infections across 48 countries between 2017 and 2023. Ten times higher than before the switch (Badizadegan et al., 2022).

Then came COVID-19. Campaigns were interrupted and widens the immunity gap. WPV1 reappeared. cVDPV2 spread fast. By 2024, eradication had stalled. WPV1 still present in Afghanistan and Pakistan. cVDPV outbreaks stretching across Africa and Asia (World Health Organization, 2022; Badizadegan et al., 2022). A new option has been deployed: novel OPV2 (nOPV2). Built to reduce the chance of the virus turning dangerous again. Released under emergency authorization. First data suggest promise. Fewer reversions. Yet gaps in coverage, weak health systems, and uneven results keep the world from closing the door on polio (Macklin et al., 2023; Yeh et al., 2020; Thompson et al., 2024).

**2.2.1.1 Historical overview of the Global Polio Eradication Initiative (GPEI).**

The fight against infectious diseases stretches back to centuries. Humanity has curbed epidemics, invented therapies, and added years to life expectancy. Yet only once has a human pathogen been wiped from the planet which is smallpox, certified eradicated in 1980. Polio became the next great target. An infection capable of killing or crippling children, polio carried a long and uneasy history. Vaccines developed in the 1950s changed the history. Their arrival made prevention possible, and early control efforts succeeded widely, though obstacles persisted (Plan, 2011).

Poliovirus belongs to the genus Enterovirus of the Picornaviridae family. It exists in three serotypes, each built of a single-stranded positive-sense RNA genome encased in a protein shell. Translation in host cells produces a large polyprotein, later cleaved into multiple structural and nonstructural proteins. These orchestrate viral replication and pathogenesis (Mick et al., 1999; Belov et al., 2012; Shen et al., 2012). Clinical outcomes vary. Most infections remain unapparent, a minority resemble influenza, and a smaller proportion lead to paralytic poliomyelitis. Paralysis can be spinal, bulbar, or mixed, with permanent disability in many survivors (Mayer & Neilson, 2010).

Epidemics have shadowed human history. Ancient Egyptian art depicts withered limbs thought to be polio. Medical descriptions first appeared in the 19th century. By the late 1800s, epidemics swept Europe and the United States. In 1952, more than 21,000 paralytic cases were reported in the U.S. alone (Valtanen et al., 2000; Alexander et al., 2004; CDC, 1981). The eradication movement gained momentum after smallpox’s elimination. The World Health Assembly launched the Global Polio Eradication Initiative (GPEI) in 1988, inspired by early success in the Americas during the 1980s (Global Eradication Initiative, 2010a; Aylward & Tangermann, 2011). Immunization campaigns became some of the largest coordinated health interventions in history. Still, imported wild polioviruses continued to spark outbreaks in countries that had already interrupted transmission, such as Finland, the Netherlands, Bulgaria, and Romania (Hovi et al., 1986; Bijkerk, 1979; Oostvogel, 1994; WHO, 1992; Strebel et al., 1994). Political collapse and weak health systems fueled re-emergence in parts of the former Soviet Union during the 1990s (Oblapenko & Sutter, 1997; Patriarca et al., 1997).

Vaccines defined the strategy. Jonas Salk’s inactivated polio vaccine (IPV), licensed in 1955, provided systemic immunity without risk of vaccine-associated poliomyelitis. Albert Sabin’s oral polio vaccine (OPV), introduced in 1961, was cheaper, easier to administer, and induced mucosal immunity in the intestine. OPV stopped transmission rapidly during mass campaigns, but it carried rare risks of vaccine-associated paralytic poliomyelitis (VAPP) and, over time, the emergence of circulating vaccine-derived polioviruses (cVDPVs) (Luther, 1962; Henderson, 1964; Schonberger et al., 1976; Kew et al., 2004). By the 2000s, high-income countries adopted IPV schedules, while low-resource and endemic regions continued with OPV because of cost and logistics (Global Polio Eradication Initiative, 2010b–e; Martin et al., 2013).

Despite setbacks, global coverage rose. By 2010, about 85 percent of children worldwide had received three doses of oral vaccine, though disparities remained at national and subnational levels (CDC, 2011d; Hopkins, 2013). India celebrated one year without a polio case in January 2012, a landmark given the country’s previous burden (CDC, 2011a, 2011b, 2011c). Endemic transmission, however, persisted in Nigeria, Afghanistan, and Pakistan, driven by political instability, community mistrust, and fragile health systems (Hopkins, 2013). The cost of eradication was estimated at $9.5 billion from 1988 to 2013 (Global Polio Eradication Initiative, 2010d). Yet even with vast investment, new challenges arose. Genetic sequencing revealed poliovirus in Egyptian sewage linked to strains circulating in Pakistan, years after Egypt’s certification as polio-free (Roberts, 2013). Outbreaks of cVDPVs underscored the double edge of OPV. The disparity between IPV use in wealthy nations and continued reliance on OPV in poorer countries exposed a global fault line. By 2012, experts still aimed to interrupt wild poliovirus transmission, but fatigue among donors, political instability, and repeated outbreaks made the goal elusive.

**2.2.1.2 Milestones in Nigeria’s Polio Eradication Journey.**

Nigeria’s fight against polio shows how fragile progress can be when public trust collapses. Resistance in the north, especially in Kano and neighboring states, took root in the early 2000s. Rumors spread that the vaccine carried infertility drugs, HIV, or cancerous agents. Suspicion of Western medicine was strong, and campaigns faltered (Jegede, 2007; Mohammed et al., 2009). The pause in vaccination created gaps that allowed wild poliovirus to circulate.

Community engagement had to change. The CORE Group Partners Project (CGPP), introduced in 2014, relied on women recruited from their own towns and villages. These volunteer community mobilizers gained credibility through proximity and persistence. They visited homes. They listened. They countered misinformation in familiar language. Over time, their presence softened distrust and shifted local attitudes (Usman et al., 2019; Duru et al., 2019). Traditional rulers and religious leaders added their weight, lending legitimacy to the effort. Without this layer of social acceptance, eradication would not have advanced.

Surveillance became another cornerstone. Nigeria needed to track every case of acute flaccid paralysis, every missed child, every resistant household. The VCMs doubled as field observers. They joined NGOs and independent monitors to ensure gaps were exposed quickly. Health camps appeared in settlements displaced by conflict. House-to-house visits and compound dialogues kept the campaign visible. Data flowed upward, giving health workers and politicians little room to ignore weaknesses (Hamisu et al., 2018; Nasir et al., 2016). Accountability followed. The National Polio Emergency Operations Centre forced states to defend their coverage rates before peers, governors, and even the president. If immunization fell below the 80 percent benchmark, corrective steps were imposed. This structure kept pressure on local authorities and gave donors evidence of transparency. Constant monitoring by groups outside government made it harder to dismiss failures (Duru et al., 2019). Partnerships carried the weight of resources. Nigeria’s eradication drive leaned on the Bill & Melinda Gates Foundation, Rotary International, WHO, UNICEF, and CDC. Local NGOs filled staffing gaps and extended reach into communities that government could not cover. Immunization campaigns added incentives which includes bed nets, deworming tablets, vitamin A supplements that help to reassure parents that health workers brought genuine benefit (Abimbola et al., 2013; Perry et al., 2019).

**2.2.2 Surveillance Approaches for Poliovirus**

**2.2.2.1 Acute Flaccid Paralysis (AFP) surveillance**

Acute flaccid paralysis (AFP) surveillance is a standardized, case-based syndromic surveillance system used globally (WHO, 2024). It employs uniform tools, indicators, and reporting systems across all countries, thereby strengthening collaboration with immunization partners through the timely sharing of weekly data (WHO, 2023). This standardization enables early detection of risks and weaknesses and facilitates coordinated responses (Badizadegan & Thompson, 2025). AFP surveillance is critical because poliovirus infections are difficult to detect. Only about one in 200 infections with wild poliovirus (WPV) in non-immune individuals results in paralysis (WHO, 2024). Most infections are “silent,” producing no clinical symptoms. Furthermore, when paralysis does occur, it may mimic other conditions such as Guillain-Barré syndrome (GBS). To address these challenges, the Global Polio Eradication Initiative (GPEI) adopted two key measures in the 1980s: (1) designating AFP as a reportable condition, and (2) confirming poliovirus through laboratory testing of stool specimens in World Health Organization (WHO)-accredited laboratories (WHO, 2024).

Prior to GPEI, polio was reported as a clinically confirmed condition within general disease surveillance systems, often only annually. This limited sensitivity and responsiveness in detecting outbreaks (Badizadegan & Thompson, 2025). By adopting AFP as the reportable syndrome, health systems became more sensitive to potential cases of poliovirus. An AFP case is defined as any child under 15 years presenting with sudden-onset floppy paralysis or muscle weakness from any cause, or any person with suspected poliomyelitis. This definition captures a wide range of conditions, including poliomyelitis, GBS, transverse myelitis, and traumatic neuritis. Laboratory investigation is therefore essential to confirm the underlying cause (WHO, 2024).

To measure sensitivity, the non-polio AFP detection rate serves as a key indicator. In polio-free contexts, surveillance systems are expected to detect at least one non-polio AFP case per 100,000 children under 15 years annually. In outbreak-affected or high-risk countries, the target is at least two cases per 100,000, while in endemic areas it is at least three per 100,000. Testing stool samples remains the gold standard for confirming poliovirus infection. Two specimens collected 24 hours apart, within 14 days of paralysis onset, must be sent to WHO-accredited laboratories. At least 80% of reported AFP cases should meet this standard to ensure adequate surveillance sensitivity (WHO, 2024).

**Strategies for AFP Surveillance**

AFP cases are identified using three main strategies:

1. **Routine (passive) surveillance:** Regular reporting by health facilities, sometimes referred to as zero reporting, where sites must submit weekly reports even if no cases are detected.
2. **Active surveillance (AS):** Surveillance officers visit reporting sites regularly to verify case reporting, strengthen compliance, and identify missed AFP cases.
3. **Community-based surveillance (CBS):** Community volunteers and non-traditional reporting networks assist in identifying suspected AFP cases, particularly in underserved or hard-to-reach populations.

Despite its strengths, AFP surveillance faces limitations such as incomplete reporting networks, inconsistent weekly reporting, high staff turnover, declining awareness about polio, and confusion between passive and active surveillance approaches (Badizadegan & Thompson, 2025). These challenges can delay detection and weaken the sensitivity of the system. Strengthening active surveillance and community engagement can help mitigate these weaknesses.

**Environmental Surveillance (ES): Principles, Processes, and Added Value**

**Principles of Environmental Surveillance**

Environmental surveillance (ES) involves monitoring the circulation of enteric pathogens in a population through sewage samples containing human fecal material (Hovi et al., 2012). Unlike acute flaccid paralysis (AFP) surveillance, which relies on symptomatic case detection, ES identifies pathogen shedding in stool, capturing both symptomatic and asymptomatic infections. This makes ES particularly valuable for detecting “silent transmission” that cannot be observed through clinical surveillance alone. Poliovirus eradication efforts increasingly rely on ES due to the limitations of AFP surveillance. As the incidence of paralytic polio declines, the majority of poliovirus infections remain asymptomatic, with only about one in 200 cases resulting in paralysis. Furthermore, the clinical presentation of AFP can overlap with other conditions, and laboratory confirmation is often complex. In this context, ES has emerged as an essential complementary tool for early detection of poliovirus circulation and for monitoring the impact of immunization campaigns (Manor et al., 1999; Asghar et al., 2014).

**Processes and Technical Considerations**

The World Health Organization (WHO) first issued guidelines for poliovirus ES in 2003, recommending that sampling sites be located at inlets of sewage treatment plants or other major collector sewers (WHO, 2003). The success of this strategy depends on several conditions:

1. A functioning sewerage system that serves the majority of the population, including high-risk groups.
2. Reliable transport of human fecal material into the sewerage system.
3. Sufficient environmental persistence of the target pathogen.
4. Sensitive and specific laboratory assays capable of detecting the pathogen in concentrated sewage samples.

Where sewerage networks are absent or fragmented, ES is more difficult to implement effectively. Challenges such as inconsistent sewage flow, pathogen dilution, and rapid viral decay can reduce detection sensitivity. In such contexts, models are needed to guide site selection and sampling strategies. For pathogens less environmentally persistent than poliovirus, such as *Salmonella Typhi*, ES may have more limited utility.

**Added Value of Environmental Surveillance**

The greatest contribution of ES is its ability to detect poliovirus transmission earlier and more comprehensively than AFP surveillance alone. Comparative studies highlight several advantages:

* Early detection: ES often identifies poliovirus circulation weeks or months before AFP cases are reported. In Pakistan, ES detected genetically related poliovirus strains more than 200 days before the onset of clinical symptoms in associated AFP cases (Cowger et al., 2017; Alam et al., 2014).
* Silent outbreak detection: ES has revealed circulation in the absence of reported AFP cases, as documented in Israel and Nigeria, demonstrating its capacity to detect silent transmission (Manor et al., 1999; Asghar et al., 2014).
* Reduced orphan viruses: The frequency of “orphan viruses” (isolates with significant genetic divergence, indicating prolonged undetected circulation) declines when ES supplements AFP surveillance. This suggests a more complete capture of transmission chains.
* Programmatic decision-making: Early signals from ES allow health authorities to implement timely immunization campaigns, strengthen routine immunization, and target high-risk populations more effectively. In Lahore, Pakistan, detection of WPV through ES informed rapid vaccination interventions that helped prevent wider spread (Asghar et al., 2014).

**Strategic Integration with AFP Surveillance**

While AFP surveillance covers entire national populations, ES is geographically limited to populations served by specific catchment areas. Nevertheless, ES can detect cross-regional or even cross-border transmission, as seen when viruses from Afghanistan were first detected in Pakistani ES sites before AFP confirmation (Shaukat et al., 2014).

Together, AFP and ES form a synergistic system: AFP provides wide national coverage, while ES offers enhanced sensitivity and early-warning capacity. The integration of both approaches has been critical for maintaining progress toward eradication in high-risk countries such as Pakistan, India, and Nigeria.

**Table 1. Comparison of AFP and ES for Poliovirus**

| Feature | (AFP) Surveillance | Environmental Surveillance (ES) |
| --- | --- | --- |
| Principle | Case-based syndromic surveillance targeting children <15 years with sudden-onset flaccid paralysis. | Monitoring sewage/wastewater for poliovirus excreted by infected individuals (symptomatic or asymptomatic). |
| Detection Scope | Detects only paralytic cases (about 1 in 200 infections). | Detects both symptomatic and asymptomatic infections through stool shedding. |
| Sensitivity | Limited; dependent on timely reporting, case investigation, and stool collection. | Higher; can detect silent circulation and outbreaks before AFP cases appear. |
| Timeliness | Often lags; relies on clinical presentation and reporting. | Provides early warning, sometimes months before AFP confirmation. |
| Laboratory Role | Stool specimens tested in WHO-accredited labs to confirm poliovirus. | Concentrated sewage samples tested in WHO-accredited labs to isolate poliovirus. |
| Coverage | National, as all health facilities are reporting sites. | Geographically limited to populations connected to sewerage systems or catchment areas. |
| Key Indicators | - ≥1 non-polio AFP case per 100,000 children annually in polio-free areas. - ≥80% adequate stool specimen collection. | No universal quantitative indicator; sensitivity depends on sewage coverage, viral persistence, and laboratory performance. |
| Strengths | Standardized, globally adopted; ensures systematic detection and response; captures differential diagnoses. | Detects silent circulation; provides early signals; reduces “orphan viruses”; informs immunization campaigns. |
| Limitations | Cannot detect asymptomatic infections; prone to underreporting; delayed detection. | Requires functioning sewer systems; geographically limited; technical challenges in sampling and interpretation. |
| Programmatic Value | Provides broad national surveillance data to support certification of eradication. | Acts as an early-warning system; guides timely interventions and targeted immunization campaigns. |
| Best Use | Universal baseline surveillance for all countries. | Complementary tool in high-risk, endemic, or outbreak-prone areas to enhance sensitivity. |

Source: Researcher’s Computation from WHO (2023, 2024)

**2.3 Empirical Review**

**2.3.1 Global Empirical Contributions of Environmental Surveillance (ES) to Polio**

Manyanga et al. (2025) conducted an evaluation of environmental surveillance (ES) in South Africa to supplement acute flaccid paralysis (AFP) surveillance. The study assessed 16 ES sites across eight metropolitan health districts between 2020 and 2023 using both secondary data and qualitative field visits. Findings revealed that 97.9% of collected samples reached the National Institute for Communicable Diseases within 72 hours, with monthly sampling increasing significantly from 18% in 2020 to 32.5% in 2021 (p = 0.0085). Although no significant differences were observed in enterovirus isolation rates between virtually and physically trained sites, operational variability was noted in densely populated cities. The study concluded that while ES is progressing in South Africa, attention to irregular sampling and peak-hour collection strategies is required to enhance performance and scalability across the region.

Similarly, Alam et al. (2014) reported on Pakistan’s ES program, which began in 2009 and rapidly expanded to 27 sites across four provinces. Between 2011 and 2013, 668 samples were collected, with 40% testing positive for wild poliovirus type 1 (WPV-1). The highest detection rates were observed in Peshawar (82%), Karachi-Gadap (69%), and Rawalpindi (65%). Phylogenetic analysis revealed multiple WPV-1 lineages circulating across provinces and crossing into Afghanistan. The authors concluded that ES in Pakistan was a powerful tool for identifying poliovirus circulation in the absence of AFP cases, thereby strengthening cross-border eradication efforts.

Cowger et al. (2017) further demonstrated the critical role of ES in Pakistan between 2011 and 2013 by analyzing over 1,100 WPV isolates. Their study found that ES detected circulation before AFP in nearly 60% of polio cases, with an average lead time of 118 days. Importantly, combined ES and AFP surveillance reduced the proportion of “orphan viruses” (undetected circulation) from 7.7% under AFP alone to 3.3%. The study emphasized that ES provided earlier and more sensitive detection than AFP alone, reinforcing its strategic role in eradication endgame planning.

In Ghana, Baguune et al. (2024) evaluated the ES system in the Northern Region from 2019 to 2020 using CDC guidelines. Among 48 samples collected, one tested positive for circulating vaccine-derived poliovirus (cVDPV), which triggered enhanced AFP surveillance and subsequent vaccination campaigns. The evaluation highlighted high completeness (97.9%) and timeliness in sample collection, as well as stakeholder commitment. However, feedback mechanisms from national to regional levels required strengthening. The study confirmed that ES was both useful and acceptable for outbreak detection and program response.

Evidence from China also illustrates the complementary role of ES. Chen et al. (2020) reviewed AFP and ES data from Shandong Province between 1991 and 2018. Of the 352 sewage samples collected, 61.6% were positive for poliovirus, including one detection of vaccine-derived poliovirus type 2 (VDPV2). While no wild poliovirus was isolated during the review period, ES proved valuable in identifying a wide diversity of enteroviruses and vaccine-associated polioviruses, thereby complementing AFP surveillance in monitoring poliovirus circulation during the polio endgame strategy.

At the global level, Hovi et al. (2012) provided an overview of ES contributions, emphasizing its sensitivity in detecting poliovirus excretion in both symptomatic and asymptomatic individuals. The study highlighted how WHO incorporated ES into its strategic plan for 2010–2012 as a supplement to AFP surveillance. Under optimal conditions, ES was found to be more sensitive than AFP, particularly in contexts where asymptomatic infections dominated transmission dynamics. Collectively, these empirical studies demonstrate the critical role of ES in enhancing the sensitivity, timeliness, and effectiveness of polio eradication programs worldwide. While AFP surveillance remains the gold standard, ES provides earlier detection, identifies silent circulation, and informs timely immunization responses. The global experience show the importance of integrating both surveillance approaches to sustain progress and achieve final eradication.

**2.3.2 Empirical Contributions of Environmental Surveillance (ES) to Polio in Nigeria**

Johnson et al. (2016) conducted a study titled *Contribution of Environmental Surveillance Toward Interruption of Poliovirus Transmission in Nigeria, 2012–2015*. The study examined how environmental surveillance (ES) complemented acute flaccid paralysis (AFP) surveillance in guiding key interventions against poliovirus transmission. Using the grab method, 1.75 L of raw sewage was collected every 2–4 weeks and analyzed in polio laboratories. Between 2012 and 2015, ES identified 97 circulating vaccine-derived polioviruses type 2 (cVDPV2) and 14 wild polioviruses. For instance, in 2014 alone, 54 cVDPV2 cases and one WPV1 case were reported. These findings triggered mass immunization campaigns in Borno and Yobe States, where over 4.7 million doses of oral and inactivated polio vaccines were administered. The study concluded that ES played a crucial role in early detection and informed rapid response strategies that contributed to the eventual interruption of transmission.

Hamisu et al. (2022) conducted a study titled *Characterizing Environmental Surveillance Sites in Nigeria and Their Sensitivity to Detect Poliovirus and Other Enteroviruses*. The study assessed how site characteristics affect ES sensitivity in a resource-constrained setting. Using quarterly data from 78 ES sites across 21 states between June 2018 and May 2019, the researchers matched 1,345 samples with site features such as catchment population, water quality, and sewage flow. Mixed-effects regression and machine learning models showed that higher pH, larger catchment populations, and elevated dissolved solids were significantly associated with higher enterovirus detection rates (average prevalence = 68%). The random forest model predicted high-performing sites (>70% prevalence) with 75% sensitivity and specificity. The study recommended simple measurement tools and population estimates as cost-effective strategies to strengthen surveillance sensitivity.

Dankoli (2019) conducted a study titled *Environmental Surveillance and Vaccine-Derived Poliovirus Type 2 Isolation, Gombe State, Nigeria*. The study compared ES and AFP surveillance yields between January 2017 and June 2018. A total of 309 sewage samples from five ES sites and 142 AFP stool samples were analyzed. ES detected three VDPV2 isolates (0.97%), 102 non-polio enteroviruses (33.01%), and 41 negative samples (13.27%). In contrast, AFP surveillance detected no VDPV2, with a much lower NPEV detection rate of 9.16%. The findings demonstrated the superior sensitivity of ES in detecting poliovirus circulation, even in the absence of AFP-confirmed cases. The study concluded that ES provided critical early warning capacity and should be expanded alongside AFP systems.

Nightingale et al. (2025) conducted a study titled \*Sub-national Estimation of Surveillance Sensitivity to Inform Declaration of Disease Elimination: A Retrospective Validation Against the Elimination of Wild Poliovirus in Nigeria\*. The study developed a statistical framework to estimate the sensitivity of ES and AFP in confirming elimination of WPV1 at the local government authority level. Retrospective validation was performed for two poliovirus-free intervals: 2014–2016 and 2016–2020. Results showed an 85% probability of freedom from infection (FFI) after 23 months of virus absence in 2014–2016 (95% UI: 77.1–90.2%), which underestimated true circulation since WPV1 reappeared in 2016. By contrast, the probability of FFI reached 98% (95% UI: 97.9–98.7%) by 2020, aligning with Nigeria’s official elimination declaration. The study confirmed the utility of ES-derived sensitivity models for prospective eradication certification and outbreak monitoring.

Weldegebriel et al. (2015) conducted a study titled *Environmental Surveillance for Poliovirus in Polio High-Risk States of Nigeria, 2011–2012*. The study examined early ES implementation in Kano and Sokoto States using the grab sampling method. Between 2011 and 2012, 60 sewage samples were collected in Kano and 80 in Sokoto. Laboratory analysis revealed in Kano that 39 isolates (63%) were Sabin strains, 16 (26%) were cVDPV2, 2 (3%) were WPV1, 4 (6%) were non-polio enteroviruses, and 1 (3%) was WPV3. In Sokoto, 33 isolates (35%) were cVDPV2, 27 (29%) were Sabin strains, 16 (17%) were WPV1, and 17 (18%) were NPEVs. The study demonstrated ES’s capacity to detect both wild and vaccine-derived polioviruses missed by AFP surveillance, highlighting immunity gaps and the role of nomadic populations in sustaining virus transmission. The researchers recommended aggressive mop-up campaigns and targeted vaccination of underserved groups to close immunity gaps.

**2.3.3 Research Gap**

Although previous studies have provided substantial evidence of the importance of environmental surveillance (ES) in detecting poliovirus in Nigeria, several gaps remain. Early studies (Weldegebriel et al., 2015; Johnson et al., 2016) demonstrated that ES could detect wild polioviruses (WPVs) and circulating vaccine-derived polioviruses (cVDPVs) missed by acute flaccid paralysis (AFP) surveillance. However, these studies focused largely on descriptive detection outcomes without systematically quantifying ES’s contribution to early warning compared with AFP. More recent works (Hamisu et al., 2022; Dankoli, 2019) evaluated ES sensitivity and site characteristics, but they were geographically limited and did not assess ES performance in the broader context of high-risk states where surveillance sensitivity is critical. Nightingale et al. (2025) advanced the discussion by modeling surveillance sensitivity for eradication certification, but their approach relied on retrospective probabilistic estimation rather than operational field-level realities. The reviewed studies indicate that while ES enhances detection capacity and provides early warning signals, there has been limited comparative evaluation of ES and AFP performance across high-risk states in Nigeria. Additionally, there is insufficient analysis of operational challenges such as infrastructure gaps, site representativeness, and laboratory turnaround times. These gaps limit the translation of ES findings into actionable programmatic strategies for strengthening Nigeria’s polio surveillance system.