**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.

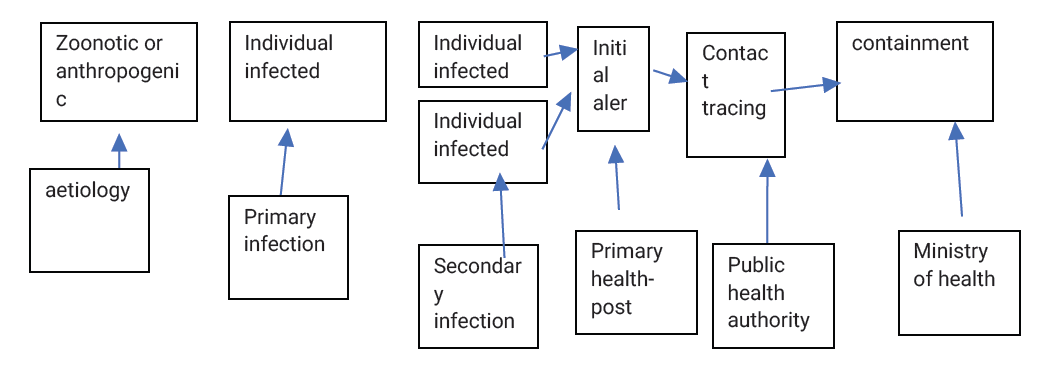


Figure 1: Public health surveillance theory framework (Dzirasah et al., 2024)

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.