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THEMATIC COLLECTION: STANDARDS & THEIR CONTAINERS ORIGINAL RESEARCH ARTICLE

"Actions Imposed by Circumstances": The Colonial Origins of The Yellow Fever Vaccine Debate, 1940s–1970s

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Abstract

Why did the French neurotropic vaccine against yellow fever remain in global use from 1945 to the early 1980s, despite mounting evidence that it could cause fatal encephalitis in small children? This paper investigates debates over the safety and efficacy of the French Dakar-strain vaccine at the World Health Organization (WHO) in the postwar years. French microbiologists argued for retaining the vaccine, citing millions of successful jabs in colonial Africa during World War II. Critics pointed to well-documented postwar cases of serious adverse effects, and the availability of a safer alternative – the Rockefeller 17-D strain. Investigating the WHO-s debate reveals how postwar decisions to retain the Dakar strain as an emergency option, next to the 17-D vaccine, were shaped by prewar epidemiological data. These, in turn were limited by colonial infrastructure and racialized logics of wartime vaccination campaigns. Though the vaccine was supposed to be used only as an emergency alternative, in practice, its ease of use in West African settings made it the default option during outbreaks for decades.

Keywords

microbiology; yellow fever; World Health Organization; colonialism; empire

Introduction

In 1944, the United Nations Relief and Rehabilitation Administration (UNRRA) mandated that all travelers arriving in regions of yellow fever endemicity be inoculated using a vaccine that met a strict set of criteria. This was a historic moment, as it made the yellow fever shot the world's first vaccine to be recognized and standardized by an international organization (UN Treaty 1944). The UNRRA authorized two vaccine strains, one developed by the American Rockefeller Foundation, called 17-D, and another one by the French Pasteur Institute, called variously the Dakar strain or the French neurotropic vaccine. This was cause for celebration, as yellow fever was (and remains) a dangerous tropical disease. Originating in Africa, this mosquito-borne viral illness was spread to the Americas by the transatlantic slave trade, where it shaped the economy, politics, and society of the country. (McNeill 2010) In benign cases, a yellow fever infection causes flu-like symptoms for a few days; about 15 per cent of patients, however, move onto a "toxic phase" that ends in

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death in about half of the cases. The virus is deadliest to adults in their prime, but childhood infections tend to be milder and confer lifelong immunity, which is why the illness has been particularly troublesome for Europeans – such as colonial officials or plantation owners – who moved to tropical regions as adults. (Barrett and Monath 2003) In short, the vaccines promised to transform the tropical regions of the world. Yet one of them caused trouble of its own.

The same year 17 children died from encephalitis in Brazzaville, French Equatorial Africa, after receiving the Dakar vaccine. A similar incident in 1951 led to 57 cases and one death (Pellissier and Trinquier 1953). In Costa Rica, twelve children inoculated with the Dakar vaccine developed encephalitis, with three fatalities. A year later, in British Nigeria - 83 cases and 32 fatalities. The symptoms and progress of illness were always similar. About two weeks after being vaccinated, children would complain of headaches and fevers, and then begin convulsing uncontrollably, starting with the head, then hands and feet, and finally the entire body (MacNamara 1953, 203). Their speech would slur, they would become disoriented and irritable, often gasping for air. Some would recover in six to twelve days, others would become paralyzed and ultimately perish. Even compared to yellow fever itself, which is notorious for its toxic phase, which can lead to whole-body bleeding, organ failure, and death, such cases of encephalitis appeared formidable.

This article uses the case of yellow fever to analyze how studies conducted in the colonial contexts of prewar campaigns shaped postwar debates over mass vaccination, a topic that has received remarkably little scholarly attention (Packard 2016, 89–131; see White 2023 for an exception). It highlights how support for mass vaccination depended on epidemiological evidence and technologies dating from the interwar years. As reports from colonial campaigns became incorporated into WHO's reports on vaccine efficacy, they were removed from their historical context. Yet it was precisely this context, which included an understanding of Africans as disease reservoirs to be managed, a racialized undervaluing of African life, and the deployment of the vaccine in infrastructure-poor areas of French West Africa, that explains why instances of adverse effects were not recorded, and why the vaccine appeared so suitable for a tropical setting. In other words, tracing the colonial production of the vaccine's "success" helps explain why it was possible to dismiss postwar cases of postvaccinal infant death, and keep the vaccine in production until 1983.

Often, colonial prevention and treatment campaigns, such as tuberculosis and yellow fever vaccination (Monnais 2006; Velmet 2020), the Jamot mission against sleeping sickness (Lachenal 2013a) and the state quinine service in Indochina (Monnais 2019) revealed the limits of imperial medicine. Rather than reinforcing colonial humanitarianism, as their proponents claimed, these programs revealed how administrators favored vaccination as an alternative to more substantial investments into infrastructure and primary services. Others have shown how colonial logics were built into the very design of various pharmaceuticals, such as methods used to preserve calf lymph used in smallpox vaccination. (Brig 2022; Velmet 2019).

By contrast, historians of postwar global health have emphasized the importance of environmental control programs after World War II. Following the Rockefeller Foundation's successful campaign to "eradicate" yellow fever in Brazil in the interwar years, the WHO saw environmental sanitation as the path towards eliminating a variety of tropical diseases, such as malaria or yaws. (Cueto et al. 2019; Löwy 1997, 2001). These programs were connected to programs of development, intended to bring countries in the global South into the economic orbit of the United States with the help of US expertise (Packard 2016; Brown

et al. 2006, 65) In this telling, mass vaccination campaigns moved to the center of the WHO-s agenda only after the failure of its campaign to eradicate malaria. Mass vaccination has essentially been framed as a Cold War story. It proved to be the one process where the US and USSR could find common ground, since vaccination campaigns did not imply radical restructuring of local capacity, which could be interpreted as favoring one ideology over another. At the same time, it could be supported by imperial powers seeking to maintain their already tenuous grip over what they had left of their colonial holdings (Pearson 2018; Packard 1997; Stepan 2011).

In contrast, the following discussion, like other papers in this thematic collection, emphasizes the continuity of colonial infrastructures and knowledge in postwar debates over global health. Debates at the WHO illustrate how interwar colonial politics and infrastructure shaped both what could be known about the vaccine as well as how it could be used. I argue that colonial infrastructure produced ignorance about the vaccine's dangers. Building on studies focused on the politics of bioengineering decisions in smallpox (Brig 2022; Naono 2009) and tuberculosis (Monnais 2006; Velmet 2019) vaccination, this paper argues that the technical "simplicity" of the Dakar vaccine, expressed in its thermostability and delivery via scarification (puncturing of the skin using a bifurcated needle), was the product of a colonial logic. In the second part of the essay, I show how racialized assumptions about acceptable risk shaped decisions about how the vaccine could be used throughout its development and deployment. Finally, I show how reports of prewar success played into postwar debates at the WHO over the vaccine's continued use.

Critical to the vaccine's continued support was its designation as an emergency tool, to be used only in situations of crisis. As scholars of disaster have noted, how institutions define "crisis" situations is a profoundly political act (Redfield 2013; Lakoff 2017; Chidugu 2020). In this case, the "emergency use" designation was intended to alleviate concerns about the vaccine's safety. On the ground, however, extraordinary circumstances appeared quite regularly. In this light, the Dakar vaccine could be seen as an early instance of an "appropriate technology" (Morefield 2019; see also Farmer 1999, 21), an approach to innovation that has been criticized for its focus on cost-benefit analysis that would not be applied on technologies intended for the global north. The categorization of pharmaceuticals into primary and secondary priorities is, of course, common in WHO recommendations – take for instance the "core" and "complementary" lists of WHO's Essential Medicines (WHO 2023). The question here is not so much to pass judgment on these categorizations, but to understand how they were shaped by the legacy of colonial politics, even as the pharmaceuticals in question were abstracted and removed from the contexts of their original designs.

Constructing Fourteen Million Successful Vaccinations

A central claim in various postwar risk analyses supporting the continued use of the Dakar vaccine was the success of the initial mass campaigns, which nearly eliminated yellow fever from West Africa in 1939–45. The Dakar strain's "immunological results continued to be as perfect as previously," while "thousands of African children had been vaccinated without accident," as several microbiologists noted (Laigret 1957). Certainly, the efficacy of the Dakar strain was beyond dispute, as there had been no recorded cases of yellow fever in West Africa from 1952 to 1965, a region where the disease had normally been endemic. Yet experts evoked this campaign also to argue for the vaccine's safety (Laigret 1953). Indeed, the campaign was

referenced so often, particularly by French researchers, that it basically became a cliché. In the following section, we will unpack this cliché, by using archival records from the Pasteur Institute of Dakar to look at how the data behind the successful reports was assembled. I argue that limits of the wartime vaccination campaign rendered adverse effects observed in other settings essentially invisible. The procedures by which the wartime campaign was conducted produced a colonial "papereality" (Clark 2016; see also Proctor and Schiebinger 2008) that fundamentally altered the risk calculus in future discussions.

In 1939, when the vaccine campaign was rolled out in French West Africa, the Pasteur Institute clearly understood that it could cause encephalitis. One such high-profile case had been observed in France, and tests conducted in controlled settings in Dakar were equally concerning: in one trial of four hundred human subjects, conducted in 1935, nine people out of a hundred had encephalitic reactions to the vaccine (Rigollet 1939, 50–60). The government of French West Africa nevertheless approved the vaccine for mass campaigns, where, to the great relief of Jean Laigret, the vaccine's developer, no encephalitic effects were reported. Yet a closer look at reports from the vaccination campaign suggests this might have been caused by a lack of reporting rather than the safety of the vaccine.

Laigret's decision to combine the vaccine with the smallpox vaccine, and make it deliverable through scarification further increased chances that adverse effects would be missed (Durieux 1941). Many Africans were not even aware that they were receiving a new, controversial medication. One vaccinator noted that inhabitants of the village of Brinndoukrou refused to travel to get the Laigret vaccine, since they had recently been vaccinated against smallpox. The villagers, "having been vaccinated some days earlier, did not understand why they were being forced to travel again" (Bergouniou 1940). Often, vaccinators ordered village chiefs to round up people in a predetermined location, without specifying what sort of vaccination they would be getting. This must have made the campaigns much easier to conduct, but also made it more difficult for subjects to associate adverse effects with the vaccination process.

The Pasteur Institute first conducted control tests on a small number of test subjects in the Dakar marina, and schools in Dakar and Rufisque in 1938. Pastorians reported that these tests showed up to 90 per cent of subjects had received immunity without complications. Further control tests took place in various regions of Senegal in 1939, with test groups more similar to the actual populations that would be vaccinated in the upcoming campaigns. The number of control tests, however, was small, as Dr. Maurice Peltier, the head investigator of the project, admitted, since, having received the vaccine, Africans traveled back to their homes and "had a hard time understanding the reasons for control tests, and spent little effort in participating in such efforts" (Peltier et al. n.d., 15). That year, the Pasteur Institute vaccinated close to 100,000 subjects in Senegal, but performed only 1,630 control tests. The tests, in turn, relied on the availability of subjects rather than proper randomization, and one can imagine that people who felt ill were unlikely to make the return trip to the vaccination site to get tested. Finally, the control tests were performed ten days after the original inoculation, while neurological effects, as previous cases had shown, usually presented themselves about two weeks after receiving the vaccine (ibid., 31–32 in particular for the tables). The timing of the tests, their small number, and lack of proper randomization made it impossible for Pastorians to convincingly claim that the vaccine produced no side-effects. They made this claim anyway.

Take, for instance, the 1941 vaccination campaign conducted on the Ivory Coast. This was the first such campaign undertaken in a poorly developed region, far away from the vaccine's site of production, and

happened under wartime conditions. Peltier reported that vaccinators saw no ill effects in vaccinated Africans during the campaign, and that the campaign demonstrated the "safety, efficiency, and rapidity of execution of this new method, which is surely a prelude to its generalization to all the colonies of [French West Africa]" (Durieux n.d.). In practice, however, the procedure of monitoring was so haphazard that harmful effects would have been difficult to observe. On the Ivory Coast, local chiefs were then tasked with rounding up the people to a central location, often upwards of ten kilometers from their village. Sometimes, villagers might refuse to present themselves, in which case mobile vaccination units would be sent to their location. In other cases, the villagers simply chose to ignore French orders, and vaccinators found empty villages with few people present for the procedure. Often a team of vaccinators would receive, for example, 69 doses of the Laigret vaccine, but only 5 people from a distant village would present themselves to get the shots. Sometimes, the vaccinators themselves had to "play gendarmes" and forcibly bring in people to get vaccinated (Bergouniou 1940; Vernes and Trautmann 1940). Recording vaccine safety under such conditions was difficult to imagine: vaccinators had trouble keeping an accurate count of how many injections they had made per day. Vaccinated subjects quickly returned to their native villages, refused to return for control tests and vaccinators themselves had to move on to keep to their own pressed schedule. The sheer scale of the project, combined with the lack of administrative and physical infrastructure, all happening in wartime, made it impossible to properly monitor the consequences of vaccination. One vaccinator described his mission as filled with "all kinds of difficulties," including a "a total lack of preparation, except in rare cases" on the part of the African intermediaries (Bergouniou 1940).

Pastorians in Dakar nonetheless took these early campaigns as *prima facie* evidence "that it is currently possible to vaccinate a mass of individuals against yellow fever in a minimum of time," and that "no reaction, even light, could be observed" (Durieux n.d.; Peltier n.d.). In reality, Pastorians knew very little of its actual effects on Africans outside of the privileged regions of Dakar. They constructed a narrative of an orderly and methodical campaign that resulted in 14 million successful vaccinations.

Race and Risk Analysis

Throughout the vaccine's initial roll-out in West Africa, colonial officials factored race into their risk analysis, allowing health officials wider berth when vaccinating Africans instead of Europeans. Later assessments echoed this logic, as European and American researchers labeled the Dakar strain a "vaccine for Africans," which they considered unsuitable for European travellers, for whom the 17-D strain was supposedly more suitable. While European researchers were willing to balance the dangers of post-vaccinal encephalitis against the benefits of mass vaccination in Africa, they were distinctly unwilling to use similar risk calculations on subjects vaccinated in London or in New York.

Differential treatment of colonial subjects and European citizens was the norm in interwar imperial spaces. French West Africa had separate institutions for indigenous medical assistance, public health rules that differentiated by race (for example in setting rules for quarantine or disinfection during plague outbreaks), different prescriptions for neonatal care and so on. Officially, these differentiated systems reflected the model of association, meaning that France was supposed to respect traditional African institutions, share power with local chiefs and allow West African society to transition organically to democratic rule. In practice, association was essentially acknowledging the need for local intermediaries in

running an empire on a shoestring budget, and policies enacted under this banner conveniently retained racial differentiations that kept Africans from meaningfully accessing better funded European institutions, whether in education, public service or education (Conklin 1997; Cooper 2005).

French public health officials treated African subjects as an undifferentiated mass, while French patients were considered individual Republican citizens. We see this shift in initial discussions over the Dakar vaccine's safety, after Jacqueline B's unfortunate illness in Paris raised concerns about the product's safety. Critics of the vaccine focused on risk to the individual, suggesting that as the neurotropic virus circulated in the patient's bloodstream, the "barrier between the circulatory system and the central nervous system [could be] ruptured, and that the virus passes into the nervous system, causing meningoencephalitis" (Findlay 1935, 10–11). Jean Laigret responded by focusing on *collective* risks and benefits for African populations and the importance of the vaccination program for France's benevolent civilizing mission. "If the large application of our method is approved in regions where yellow fever epidemics are suspected, we can hope that the final reservation, which refuses this benefit to the indigenous masses, can be lifted" (Laigret 1936, 7). In a speech to the Colonial Union, Laigret contrasted the risk of individual side-effects with the "cost on economic and social life in Africa that the fear of yellow fever imposes." He concluded: "Adverse events following yellow fever vaccination cannot be compared for an instant to the dangers of yellow fever itself." (Laigret 1935, 7).

When the vaccine was rolled out in 1939, French officials in West Africa imposed far more restrictions on its use on Europeans than they did on African subjects. European recipients were required to undergo a thorough medical examination prior to receiving the inoculation and were then monitored for several days after. For "the natives," "clinical examination was to be reduced to a minimum." When vaccinations were made compulsory in 1941, official instructions listed a series of contraindications for Europeans: acute illness, ongoing fevers, chronic illness, liver or kidney problems, and "in general terms, any condition that diminishes the resistance of the subject." (Durieux 1941). For Africans, the only reason for "temporary contraindication" was "acute fever." (Anon. 1941). Finally, for Europeans, the Health Service specifically prohibited "mixed vaccinations" against both smallpox and yellow fever and excluded children under the age of five altogether – both were standard practice for Africans (Robert 1941). For Europeans, prior clinical screenings and contraindications likely weeded out many recipients at risk of health complications, while for Africans, the primary concern remained mass coverage and the eradication of yellow fever altogether. Early reports of vaccination campaigns noted that successful efforts in scaling up the process "permits to imagine the possibility of sterilizing this important reservoir of the virus represented by the population of West Africa." (Governor-General of the AOF 1940).

Even given these differences in risk assessment, vaccinators still reported instances of adverse reactions, for instance among the officer corps and older recruits in the military. This led to further cautioning. "Members of the white race" were asked to "lead a calm life in the three weeks following vaccination [...] and avoid all sources of excessive fatigue: strenuous exercise, competitive sports, exhausting travel, long sun exposure, too long swims in the sea" etc. (Durieux 1941). During the UNRRA trials of the Dakar vaccine in 1945, recruits receiving the vaccine were told to refrain from exertion in the following weeks. One group of recruits, however, went on a fifteen-kilometer march in the open sun shortly after having received the vaccine, and later reported a 30 per cent rate of adverse reactions, including encephalitis

("Vaccination antiamarile" n.d.). Rather than questioning the quality of the data received from the mass vaccination programs about African patients, Pastorians interpreted these results as evidence of racial difference in vaccine tolerance. "Vaccinations are perfectly tolerated by the indigenous people of French West Africa among whom reactions are exceptional," concluded one Pastorian microbiologist in 1941. Later, in his reports to the WHO, Jean Laigret, too, continued to insist that "benign" reactions observed in North and West Africa had to mean that serious reactions were explained by "conditions of localization."

In the postwar era, the Dakar vaccine became known among microbiologists as the "African vaccine," unsuitable for use elsewhere because of adverse effects that would not be tolerated in imperial metropoles. Pastorians who disagreed with Laigret's risk assessment continuously pleaded with microbiologists at rival institutions to step in and advocate against the vaccine's rollout. Georges Stefanopolou, a Pastorian working on an alternative strain wrote several letters to the Rockefeller Foundation, accusing the Dakar strain's developers of being "not afraid to kill some of their fellow creatures to gain experience and particularly to infect negro populations who remain outside of 'statistics.'" (Stefanopolou 1934). In 1946, the Rockefeller Foundation cautioned against using the Dakar vaccine in Brazil, arguing that "[i]n dealing with native populations in Africa [. . .] vaccination by the French method and with the French neurotropic strain may be permissible. It is the feeling, however, in Brazil that it would not be advisable to apply a method, which might, though rather rarely, give rise to encephalitis." (Hahn 1946). In 1950, John S. K. Boyd, director of the Wellcome Laboratories in London enquired from the WHO about the possibility of getting approval for the manufacturing and further development of a mouse-brain vaccine. Upon learning that "the French only used the vaccine for immunizing the African population," Boyd concluded that "such a vaccine would be obviously unsuitable for the public we supply." In the US, Brazil and the UK, the Dakar vaccine was considered unacceptable for local use, even as the same experts advocated for retaining it for emergency mass vaccinations in Africa (1950).

Safety Concerns Reach the WHO

The unprecedented movement of civilians and troops across large distances during World War II both raised the problem of infectious disease and led to new innovations to contain its spread for all belligerents. Insect-borne diseases – typhus, malaria, and yellow fever – posed a particularly acute threat. Prewar development in tropical regions, such as the damming of the Upper Nile in the 1930s, contributed to the multiplication of infectious mosquitoes, while malnourishment, crowding, and the mass movement of troops created ideal conditions for the spread of disease (Mitchell 2002, 21–27). New inventions, such as DDT, developed by the Swiss company Ciba-Geigy, helped curb the impact of these maladies. Still, such innovations only underscored the need to tackle infectious disease on an international level. New biochemical and biomedical products were problematic: DDT turned out to be toxic for humans and animals, and the Rockefeller 17-D vaccine, which was based on a live, attenuated virus, occasionally reverted to virulence, causing some fatalities among American troops (Russell 2001, 129–131; Bazin 2011, 452).

It is therefore no surprise that when the UNRRA spearheaded a new International Sanitary Convention, designed to modernize pre-war international health regulations, the control of yellow fever occupied a central place in the final document (Harrison 2006; Borowy 2009). The document anticipated a massive migration of displaced persons after the end of the war, as a minimum of ten million were estimated

to have been forced to flee their native countries in Europe alone. Yet conventions regulating the surveillance and prevention of disease across borders had not been updated since the 1920s – a long time, given rapid advances in epidemiology and medical innovation (Stock 1945). The new convention focused on two areas of most rapid change: air travel and yellow fever prevention. Here, accounting for the fast pace of air travel, and the onerous requirements that quarantine and disinfection imposed on passengers, the UNRRA broke with the prevailing consensus which preferred environmental controls for stopping yellow fever (Budd et al. 2009). Instead, the convention recommended, for the first time, vaccination as the primary means of preventing yellow fever. This provision raised new issues, though: the UNRRA now had to define what criteria a suitably safe and effective vaccine had to meet.

The two vaccines available at the time shared a common "parent," but were otherwise quite different. Both the 17-D strain and the Dakar strain owed their genesis to Max Theiler, a South African virologist working at the Rockefeller Foundation, who, in the early 1930s, also advised researchers at the French Pasteur Institute. Following Theiler's guidance, French researchers developed an attenuated (weakened) version of the yellow fever virus by serial passage in the brains of lab mice – the Dakar strain. As the vaccine was eventually oriented for mass vaccination in France's African colonies, it was designed to carry a substantial dose in a single shot that could be administered using scarification. This was the method used for smallpox vaccination. It was cheap, technically uncomplicated, and deemed more culturally acceptable for local populations (Velmet 2020, 199–200). Although trials of the Dakar strain were initially haunted by adverse effects, often in the form of meningitis, later trials conducted in Africa appeared more successful. As a result, a mass vaccination campaign was rolled out in 1939. Over the course of the war years, mobile teams of vaccinators inoculated some 14 million people in French West Africa, with no reports of adverse effects.

Rockefeller researchers followed a different path, namely serial passage in a variety of different tissues (mouse embryo and chick embryo), producing finally a version of the virus that induced no neurotropic effects in rhesus monkeys or lab mice. It became the basis for the 17-D vaccine. Their vaccine had its own downsides, though. It was more complicated to transport, and had to be administered subcutaneously. Most worryingly, still produced neurotropic effects in humans. In 1941, 273 cases of vaccine-induced meningitis and one death were recorded in Brazil. It seemed that, in some cases, the vaccine virus could revert to virulence (Monath cited in Plotkin 2011).

The first question facing the UNRRA was, therefore, how to deal with possible adverse effects of the 17-D vaccine. The agency's first recommendation, published in 1945, recommended adopting a "seed lot" system, developed by the Oswaldo Cruz Institute in Brazil, where cultures used for manufacturing the vaccine would be derived from a single, highly controlled "primary seed" of the vaccine-virus, thus reducing the number of passages in the production process and consequently the possibility of virulent mutations. The regulations also mandated safety tests on mice and rhesus monkeys using both the primary and secondary seed viruses (UNRRA 1945). As trials conducted in Brazil during WWII showed, the seed lot system stabilized the production process and essentially eliminated encephalitic effects (Fox et al. 1943).

Meanwhile, Maurice Peltier, a colonial doctor, oversaw a series of trials conducted on soldiers in France in 1945, designed to determine the safety and potency of the Dakar vaccine. Though one test group had a 35 per cent rate of febrile and encephalitic reactions, the trials "registered no serious adverse effects"

and returned positive seroprotection tests in 94 per cent of cases. Citing these successful trials, and the 14 million vaccinations conducted in French West Africa during the war, the UNRRA gave the Dakar vaccine partial approval in 1946 (Peltier 1946, 1950).

New doubts about the safety of the Dakar vaccine appeared almost immediately after its approval. Camille Durieux, a Pastorian microbiologist observed a series of encephalitic reactions after vaccinating Africans in Brazzaville, French Equatorial Africa, with a mixture of smallpox and yellow fever vaccines. With some 100,000 vaccinations conducted, Durieux reported 17 deaths – though for some reason, these reports never made it further than the colony's government-general (Durieux cited in Pellissier and Trinquier 1953). Another set of 57 post-vaccinal cases of encephalitis, some of which progressed to paralysis and, in one instance, death, were recorded in Brazzaville in 1953 (ibid.). These cases, probably because they took place within French colonial territories, received little international attention. As the vaccine was adopted by countries outside the French empire, however, new cases of encephalitis continued to occur. In 1952, the Public Health Service of Costa Rica used the Dakar vaccine to deal with a sudden eruption of jungle yellow fever. The vaccine used led to "a high incidence of reactions of all grades of severity [. . .] and among those reactions were 12 cases of encephalitis in children, with three fatalities." (Stuart 1953). Finally, in 1952, 42,400 people were vaccinated with the Dakar strain in Enugu, British Nigeria, leading to 83 people being admitted to the General Hospital with post-vaccinal encephalitis, and 32 deaths. By this time, the pattern of illness had already been well documented: rare encephalitic reactions followed within 12–15 days of vaccination and normally either cleared within 5–6 days or progressed to paralysis and death (Stones and MacNamara 1955).

These last two cases brought the Dakar vaccine to the attention of the WHO, successor to the UNRRA. The agency convened an expert committee to study these worrying cases and, if necessary, update its recommendations. The deliberations of the expert committee illuminate the difficult balancing act of standardizing vaccines for tropical regions. While the dangers of the Dakar strain became increasingly difficult to deny, experts were forced to admit that for many regions in the world, the strain remained the only vaccine robust enough to be administered quickly and en masse in situations of epidemic crisis.

The first question put before the expert committee was whether the vaccine itself was to blame for the encephalitic reactions. Some researchers considered that the encephalitis might have been caused by a contaminated vaccine. For instance, a different mouse virus, such the Traube-Armstrong virus, may have been present in the brains of the mice used to produce the vaccine. In Costa Rica and Nigeria, researchers discussed, but ultimately discarded hypotheses attributing the disease to secondary infections, for example, from disease-carrying arthropods. Nor could the disease be attributed to "wild" yellow fever, which rarely caused neurological symptoms (Stuart 1953). Most of the evidence pointed towards the Dakar vaccine itself. Cases of encephalitis and paralysis had been observed already in the animal trial phase of the vaccine in the 1930s. A particularly concerning case in early human trials, dating from 1936, involved a patient called Jacqueline B., who developed a high fever, hallucinations, headaches, and narcolepsy, ultimately falling into a coma for several days while being treated at the Pasteur Hospital in Paris (Darré and Mollaret 1936). Studies from the Nigerian outbreak confirmed long-held suspicions. Laboratory tests using brain material from deceased patients confirmed that they contained a variant of the yellow fever virus, tracing the disease back

to the vaccine itself (Stones and MacNamara 1955). The question now became whether it was possible to reduce risks by modifying either the production or the deployment of the vaccine.

The most vocal defenders of the vaccine were French microbiologists, led by its developer, Jean Laigret. In his 1953 report, the Pastorian emphasized the tremendous social, economic, and epidemiological benefits of mass immunization campaigns conducted using the Dakar strain. French West Africa had seen no yellow fever epidemics since World War II, while there had been both localized outbreaks or epidemic-level events almost every year from 1927 to 1939. Laigret argued that mass vaccination had come to enable the expansion of air travel, without the fear of spreading yellow fever to India, the Far East and the Pacific, consequently improving trade and communications. Laigret admitted that the "grave" cases of encephalitis documented in Costa Rica and Nigeria were concerning, but that the vaccine had been deployed with only "benign" side effects in France, North Africa, and West Africa, where over 14 million people had been vaccinated. Laigret himself had documented 12 cases of meningitis, all benign, over the course of 25,000 vaccinations he personally conducted between 1936 and 1945 (Laigret 1953). The Pastorian suggested that "local conditions" in Costa Rica and Nigeria led to stronger reactions and demanded additional research to confirm that the Dakar vaccine was indeed the culprit. Until an alternative to the vaccine existed, the Dakar strain should continue to be used, given the benefits provided by mass vaccination (ibid.).

Emergencies in Theory and in Practice

As it became increasingly clear that the Dakar strain itself was causing neurological symptoms, WHO experts had to weigh the risks of vaccination against available alternatives. These calculations were shaped by two contexts. First, ongoing discussions at the WHO on the definition of yellow fever endemic regions, which determined cross-border vaccination requirements, made a vaccine suited for Africa quite appealing. Second, the history of colonialism critically shaped the development of the Dakar vaccine in a way that rendered it more practical precisely in tropical settings.

Throughout the 1950s, the WHO attempted to reform its recommendations for yellow fever prevention, to little avail. The critical issue had to do with defining areas of yellow fever endemicity, requiring international travelers to get vaccinated or isolate upon leaving the area, thus making sure they did not introduce the disease to yellow fever free regions with mosquito populations. The question divided the WHO in two. "Eastern countries" – India, Pakistan and Ceylon – all had populations of *Aedes aegypti*, which could carry yellow fever. Representatives from those countries worried about the danger of importing yellow fever and argued for longer isolation periods and tougher vaccination mandates. Western countries – primarily in the Americas – argued for more liberal rules and proposed to redraw areas of yellow fever endemicity, altogether reducing the number of regions to which the WHO regulations would apply. They argued that mosquito eradication using DDT and mass vaccination had been so successful as to virtually eradicate yellow fever from many of the regions covered in the original UNRRA regulations from 1945. The American Knud Stowman wrote, in a pointed letter, accusing the WHO expert committee of "Anti-American wirepulling" on behalf of the "Eastern countries"—

> The fact is that at present there are only three active yellow fever foci of limited size within the yellow fever endemic zone as ordained by WHO while Aedes aegypti have been practically eliminated from the

> greater part of the zone, thus greatly diminishing the hazard of international transmission (Stowman n.d., 2–3; see also WHO 1950 and Mahaffy 1954)

In their view, the hard work of mosquito eradication completed in countries like Brazil was being overlooked, because similar work had not been done in Africa. Stowman proposed redefining "yellow fever endemic zones" to exclude locations where prophylactic measures – such as DDT spraying or mass vaccination – had essentially eliminated the threat of yellow fever. (Kinkela 2011, 35–60) Mass vaccination, therefore, offered African colonies and newly independent countries with the possibility of not just reducing the human toll of yellow fever, but also avoid the economic restrictions mandated by the WHO.

In 1957, the WHO expert committee finally issued its recommendations. These focused primarily on standardizing the production and delivery of the 17-D vaccine, and punted responsibility for using the Dakar vaccine to the states themselves. Still, the committee emphasized the importance of the Dakar strain for regions with poor infrastructure and high yellow fever endemicity – in other words, for Africa.

> The value of an inexpensive and effective vaccine should be emphasized. By growing the virus in mouse brain, using either the Dakar strain or the 17D strain of yellow fever virus, an inexpensive vaccine can be prepared. In view of the slight differences existing between the antigenic powers of the two strains, and taking into consideration the various complications which the strains may produce, the Committee considered that the choice of the virus strain to be employed should be left to the local authorities, having due regard to the local prevalence of yellow fever and the resulting morbidity. (WHO 1957, 6).

Without saying it explicitly, the committee acknowledged the concerns around the safety of the Dakar strain, but opted not to remove it from the WHO's recommendations. Rather, local authorities were told to balance the threat posed by yellow fever against the possible complications of the Dakar vaccine.

The expert committee's recommendations were not uniformly accepted. A study group consisting of microbiologists from France, the UK, the USSR, the United States, Denmark, India, Nigeria and the Netherlands reviewed the committee's work in 1958 and decided that only the 17-D vaccine should be adopted as a standardized biological substance by the WHO. Citing "occasional severe post-vaccination reactions, including in children," the study group did not endorse the Dakar strain, but still noted that their decision should not be construed "as an indication that other vaccines had not, under special circumstances, a proper place in programmes of mass vaccination" (WHO 1959, 5). Both suggested that mass vaccination could be conducted using any vaccine strain that could be delivered via scarification. In practice, as no effective method of employing the 17-D vaccine intradermally had been developed, the Dakar strain remained the only realistic options for mass vaccination in most regions of Africa (Penthier 1957).

The technical properties of the Dakar strain were no accident. The French virus had been engineered for distribution in colonial settings, where infrastructure was thin and trained medical workers few. The development of the vaccine itself had begun in response to political turmoil surrounding a particularly deadly yellow fever outbreak in 1928. The harsh sanitary measures public health authorities imposed on Africans, but refused to apply to Europeans, who were more severely affected by the disease, caused African politicians to accuse the French of racism and resist interventions such as quarantine and sanitary cordons. The Pasteur Institute, which developed the vaccine, opted to pursue a prototype that required one shot instead of three, and could be delivered via scarification even though the single-shot prototype carried

additional safety risks, because administrators saw it as a preferable candidate for mass rollout in African colonies. (Velmet 2020).

The model for the yellow fever campaign was Eugène Jamot's war against sleeping sickness, which he conducted with military precision in Equatorial Africa. This example led French vaccinators to believe that a successful program depended on a foolproof vaccine that required minimal training to administer (Lachenal 2022, 21–35). The only real alternative to the Dakar strain, the 17-D vaccine, required subcutaneous injections. While vaccinators in Brazil had successfully used the Rockefeller vaccine, postwar administrators in French West Africa considered this method inconceivable (Laigret 1957). Vaccinators, as Laigret noted, would face "the difficulty of taking with them a large stock of syringes and sterilized needles in advance, which they were obliged to resterilize locally" (ibid., 1-2).

Moreover, scarification allowed vaccinators to combine the Dakar strain with smallpox vaccination, which sped up their work, but also increased trust among local populations. Inoculation had a long history in both Africa and Europe, and vaccination against smallpox had been compulsory and well-accepted in French colonies since 1905 (Schneider 2009, 198–201). In the interwar years, combining the two shots allowed vaccinators to move more efficiently, increase trust for the yellow fever shot, but – as evidence from the field shows – also left many Africans in the dark about the new vaccine they received (Velmet 2020).

F. N. MacNamara and others did attempt to repurpose the 17-D strain for dermal delivery but found the results underwhelming (MacNamara 1957). The 17-D vaccine had other deficiencies, too, which became critical in resource-poor settings. 17-D had low thermostability, meaning that it had to be kept refrigerated, and had a generally lower shelf life than the Dakar strain – the latter could be kept at a temperature of 25°C for a month without it losing potency. These qualities made the 17-D vaccine unsuitable for tropical campaigns, which required transport across great distances, often with only basic equipment and in tropical heat. Finally, as the French vaccine's defenders continued to remind the WHO, the 17-D strain did not have a spotless track record either. French-speaking Africa, meanwhile, had two decades of experience using the Dakar vaccine for mass vaccinations. Given the vaccine's favorable profile for Africa, it remained in use despite the risks.

In 1965, after thirteen years of "total absence," yellow fever broke out in newly independent Senegal (Chambon 1967, 113). The hot zone was concentrated in an area of 50 by 60 kilometers near the counties of Diourbel, M'Backé and Bambey, with a population of 137,000. The first case was recorded on November 12 at the Diourbel hospital, and the outbreak concluded rapidly in December, "no doubt thanks to the combined effects of mosquito control and vaccination" (Chambon 1967, 116). All told, public health authorities recorded 140 deaths.

Yellow fever fatalities were disproportionately concentrated among the young: 90 per cent of deaths were among children aged ten or younger – most likely because older Senegalese still had immunity from mass vaccination campaigns undertaken in the 1940s. Concerned about the spread of the disease, public health authorities initiated a new vaccination campaign focused specifically on children. This meant vaccinating some two million people. Although the local Pasteur Institute, in accordance with the WHO's standards, had contraindicated the Laigret Vaccine for children under the age of ten, it was clear that the Institute had neither an adequate supply of the 17-D strain nor the manpower to administer it to hundreds of thousands of children. Officials had to act quickly, as the Senegalese capital, Dakar, was only 140

kilometers from the heart of the outbreak. Local health officials decided to lower the age requirement of the Laigret Vaccine to two years in the hot zone, and to five years in the surrounding region. Shortly after the vaccinations, authorities in Dakar observed 240 cases of encephalitis, and 25 deaths. (ibid., 145–148) Put differently, some 15 per cent of the fatalities during the yellow fever outbreak were caused not by the disease, but by the vaccination efforts.

The 1965 vaccine disaster has some troubling similarities to previous cases in Costa Rica and in Nigeria. In 1951, an outbreak of jungle yellow fever (yellow fever transmitted from monkeys to humans via mosquitos) in Panama led Costa Rica to rapidly conduct an immunization campaign, and given the urgency of the matter, the Laigret Vaccine was employed (Stuart 1953). In 1952, the township of Enugu was vaccinated quickly in response to a nearby outbreak, also utilizing the Dakar vaccine, which could be delivered quickly by the Pasteur Institute of Dakar, and rolled out by African vaccinators who were familiar with smallpox vaccination, which the Dakar method resembled. (Stones and MacNamara 1955, 177) As the head of the Dakar Pasteur Institute put it after the 1965 epidemic, the use of the Dakar strain was "imposed by circumstances" (Chambon 1967, 146).

The WHO set out guidelines for administering the 17-D strain, but did not account for diversity of local settings, where yellow fever outbreaks occurred. In many such places, the infrastructure for deploying the 17-D vaccine simply did not exist, while the Dakar strain was deliberately designed by colonial Pastorians for mass campaigns in resource-poor settings. The WHO was aware of this discrepancy and addressed it by allowing the use of the increasingly controversial strain in "special circumstances." Yet in cases of epidemic emergency, the "circumstances" inevitably pushed public health authorities to embrace the vaccine. Epidemic crisis made a standard out of the exception.

Conclusion

After the 1965 epidemic and the disaster with the Dakar strain, the WHO intensified its call to develop alternatives to the Dakar strain and began to look more seriously into vaccination protocols during emergencies. The use of easy-to-use jet-injectors, as opposed to syringes, expanded the potential of the 17–D vaccine for use in mass vaccination campaigns and during emergencies. In 1971, P. Brès at the WHO estimated that, given efficient crowd control, between 500–3,000 people could be vaccinated using a jet injector *per hour*. To further reduce the need for improvisation during emergencies, in 1971 the WHO "provided for the assembly of a permanently available stock of two million vaccine doses and for a team ready to go into action immediately" (Brès 1971, 2). The organization also called for research to improve the 17-D strain's thermostability (Cornet et al. 1971). Finally, it recommended the Dakar vaccine not be used in children under the age of 14. (WHO 1971). As mass vaccination programs in West Africa had effectively ceased after decolonization, and local laboratories shifted their production to the 17-D vaccine, by the early 1980s, the Dakar strain had effectively been discontinued (Brès 1983). As jet injectors and local stockpiles of the 17-D vaccine obviated the advantages of the Dakar vaccine, the strain simply fell out of use.

The story of the Dakar vaccine shows how the global standardization of vaccine campaigns can occlude the contextually specific interplay of microbes, local infrastructure, and political dynamics. In the process of standardizing guidelines for vaccine deployment, experts at the WHO naturalized epidemiological data and technical parameters that were, in fact, profoundly shaped by colonial power relations. Data from

the 1939–45 campaign demonstrated for Jean Laigret and other defenders of the Dakar strain the safety of their preferred vaccine. What the data did not show were the conditions under which different populations were treated. Europeans – who could be surveilled – had to follow strict protocols and contraindications, while Africans – who could not be monitored for neurological symptoms which normally took around two weeks to appear – were vaccinated almost without exception. And while the WHO recommended reserving the Dakar vaccine for emergency use, its design for tropical mass campaigns meant that it would become the vaccine of choice in almost every yellow fever outbreak in West Africa. Deliberations over standards at the WHO abstracted away the colonial context of the vaccine's genesis, yet the postcolonial conditions on the ground continued to shape its deployment in the postwar years.

The popularity of low-cost technical fixes designed for the global South has only grown in recent decades. Anthropologists have called the paradigm of "cost-effectiveness" the "leading calculus" of global public health. (Farmer 1999) Weighing the technical complexity and cost of a particular intervention against the supposed outcomes of interventions has led international institutions, from the WHO to the World Bank, to advocate for minimalist public health measures for resource-poor countries, leading to a dearth of treatment in the case of many conditions, such as HIV or multidrug resistant tuberculosis. Historians have shown how these logics, which accept the technical and economic boundaries of different public health approaches as fixed givens, rather than as social constructions that could be bargained over or redesigned, have deeper roots. Heidi Morefield has traced the concept of "appropriate technology" to shifts in US development assistance programs in the late 1960s. (Morefield 2019) Guillaume Lachenal has looked at how minimalist prevention programs in contemporary West Africa invoke colonialist public health projects of the interwar years (Lachenal 2013b). The debate over the Dakar vaccine shows the impact of colonialism on the period of postwar development, which has generally been seen as a moment of rupture with prior practices. Colonial infrastructures continue to shape the medical technologies to which they have given birth, even as processes of global standardization have effaced some of these birth marks from our immediate field of view.

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