

The Cholera Outbreak in Haiti: Where and how did it begin?

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Abstract In October 2010, cholera appeared in Haiti for the first time in nearly a century. The Secretary-General of the United Nations formed an Independent Panel to “investigate and seek to determine the source of the 2010 cholera outbreak in Haiti”. To fulfill this mandate, the Panel conducted concurrent epidemiological, water and sanitation, and molecular analysis investigations. Our May 2011 findings indicated that the 2010 Haiti cholera outbreak was caused by bacteria *introduced* into Haiti as a result of human activity; more specifically by the contamination of the Meye Tributary System of the Artibonite River with a pathogenic strain of the current South Asian type *Vibrio cholerae*. Recommendations were presented to assist in preventing the future introduction and spread of cholera in Haiti and worldwide. In this chapter, we discuss both the results of the Independent Panel’s investigation and the context the report sat within; including background information, responses to the report’s release, additional research subsequent to our report, and the public health implications of the Haiti cholera epidemic.

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1 Introduction

1.1 History of Haiti

In 1492, Columbus first landed in the new world at Cap-Haiten on the northern coast of the island of Hispaniola; now comprised of Haiti and the Dominican Republic (Prince 1985). The native Taíno population was exploited for gold mining and by 1548 (56 years after Columbus landed) the Taíno population dropped from an estimated 500,000 to less than 500. In 1519, sugar and cattle farming, worked by slaves, replaced worked-out gold mines as the economic foundation of the island. From 1519 to 1549, 864,000 slaves were brought to Haiti.

Over time, France began to wrest with Spain over Hispaniola, and took control of the western portion of the island (modern day Haiti) in 1697. In 1801, slave leaders led a revolt against the French, and Haiti declared independence on January 1, 1804. Haiti thus became the first black republic in the world and the second free state in the western hemisphere. France officially recognized Haiti in 1825, on the condition that compensation for lost income due to confiscation of property be paid. Haiti paid this debt until 1922.

A number of different political leaders led Haiti between 1804 and 1915, and a stable political system was never established. From 1915 to 1934, the United States occupied Haiti after seven different presidents were in power from 1910 to 1915.

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A number of dictators led Haiti from 1934 to 1956. In 1956, Francois Duvalier, with support from the black middle class and isolated rural poor, won the presidency, and his son, Jean Claude, succeeded him after his death in 1971. The Duvalier regime was characterized by rule by private militia, violence, amendment of the constitution, personal wealth, and intermittent support from the United States.

In 1986, a combination of popular uprising and withdrawal of United States support led Jean Claude Duvalier to flee to exile in France (Macquire et al. 1996). In February 1991, after a period of civil unrest, a young priest named Jean-Bertrand Aristide was inaugurated into the presidency in what is widely regarded as the first democratic election in Haiti. His Lavalas ('cleansing flood') party survived only until a coup in September 1991. Aristide escaped to the United States, and the army regained power.

In October 1991, the United States established economic sanctions against the military regime and then occupied Haiti again in 1994. On October 15, 1994, Aristide was reestablished as the Haitian president, with one and a half years left in his constitutionally mandated 5-year term. Aristide was replaced by his successor, Rene Préval, in 1996, reelected President in November 2000, and forced into exile in 2004. The United Nations Stabilization Mission in Haiti (MINUSTAH) peacekeeping force was established in response to the political turmoil of 2004. Rene Préval was reelected president in 2006, with a constitutionally mandated 5 year maximum term ending in 2011.

1.2 Haiti Geography and Environment

Haiti encompasses 27,750 square kilometers of the western third of the island of Hispaniola in the Caribbean Sea (Library of Congress—Federal Research Division 2006). The majority of Haiti's land (63 %) is considered too steep for agricultural production; however, nearly 80 % of the country's area functions as agricultural land. Deforestation is extreme in Haiti, as forests covered nearly 60 % of the country in 1923, and only 2 % by 2006. Most Haitians still depend on charcoal as their primary fuel and cooking source. This deforestation has led to soil erosion, which has decreased agricultural yields and resulted in deadly landslides.

The 2010 population of Haiti was estimated at just under 10 million, with 3 million in the capital city of Port-au-Prince (UNICEF 2012). Haiti is the poorest country in the Western Hemisphere, with a per capita income of 650 USD/year and 55 % of the population living below the world poverty line of 1.25 dollars per day. The life expectancy in Haiti is 62 years and adult literacy is 49 %. In 2008, 63 % of the population had access to improved drinking water (71 % of urban residents and 55 % of rural residents) and 17 % of the population had access to improved sanitation.

The development of sustainable water and sanitation infrastructure in Haiti has been hindered by ongoing political instability and lack of investment. In 1964, the government agency CAMEP was established with responsibility for the drinking water supply in Port-au-Prince. In 1977, the government agency SNEP was

established with responsibility for water supply in secondary cities. During this time, the rural water supply situation was managed by the government agency POCHEP in the Ministry of Public Health.

In January 2009, the Haitian Parliament approved a water and sanitation sector reform bill, which formalized sector reform. The law created a National Directorate of Water Supply and Sanitation (DINEPA) in the Ministry of Public Works, Transport, and Communications, as well as four Regional Offices of Drinking Water and Sanitation (OREPAs). The role of DINEPA is to execute the government guidelines in the water and sanitation sector by developing water and sanitation sector regulation and monitoring stakeholders in the sector.

1.3 January 12, 2010 Earthquake

On January 12, 2010, a 7.0 magnitude earthquake struck 17 km southwest of Port-au-Prince, Haiti. Nearly one-third of Haiti's population, almost three million people, were affected by 'extreme', 'violent', or 'severe' shaking (USGS 2010). An estimated 222,650 people died and 310,930 were injured (OCHA 2013a). This powerful quake in an area of poor quality construction materials caused extensive damage to shelters. The building damage assessment conducted from March 2010 to February 2011 indicated 403,176 buildings were damaged or destroyed (OCHA 2013a). Out-migration of an estimated 482,000 people from affected areas also strained resources in rural Haiti (CDEMA 2010). In addition, many schools and hospitals were destroyed (OCHA 2013a).

The immediate humanitarian response was complicated by the: (1) inability to import goods due to damage to the airport and port; (2) inability to transport goods due to rubble and temporary shelters blocking roadways; (3) loss of life and resources within humanitarian organizations; (4) communications difficulties; (5) lack of staff capacity to respond; and (6) the overwhelming scale of the disaster. The water, sanitation, and hygiene emergency response Cluster estimated 1.1 million people hosted in approximately 651 spontaneous settlements in Port-au-Prince, Jacmel, Gressier, Léogâne, Grand Goâve, and Petit Goâve were in immediate need of services (OCHA 2010).

Over time, as the response continued, the number of people housed in spontaneous settlements fell from a high of 1,536,447 in July 2010 to 420,513 in April 2012 (IASC 2012). However, as of April 2012, 70 % of water points in these settlements had no free chlorine residual, 95 % of residents did not have access to 10 l of water per day, and only 3 % had adequate handwashing facilities with soap and water.

In the Center for Disease Control and Prevention's (CDC) "Haiti Pre-decision Brief for Public Health Action Cholera", the CDC wrote "Cholera is extremely unlikely to occur" as "Epidemic cholera has not been reported from Haiti before" and "An outbreak of cholera is very unlikely at this time (CDC 2010). For a cholera outbreak to occur, two conditions must be met: (1) there must be significant breaches in the water, sanitation, and hygiene infrastructure used by groups of people,

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permitting large-scale exposure to food or water contaminated with *Vibrio cholera* [sic] organisms; and (2) cholera must be present in the population. While the current water, sanitation, and hygiene infrastructure in Haiti would certainly facilitate transmission of cholera (and many other illnesses), cholera is not circulating in Haiti, and the risk of cholera introduction to Haiti is low. Most current travelers to Haiti are relief workers from countries without endemic cholera, and they are likely to have access to adequate sanitation and hygiene facilities within Haiti, such that any cholera organisms they import would be safely contained.”

1.4 Cholera

Cholera is a severe, acute, dehydrating diarrhea that can kill children and adults in less than 12 h, and is the result of infection with a pathogenic strain of the bacterium *Vibrio cholerae*. The organism is capable of producing a potent toxin known as cholera toxin (CT). Depending on the severity of the infection, cholera may be treated with oral rehydration salt (ORS) solutions, intravenous fluids, and/or antibiotics. *V. cholerae* infection displays a clinical spectrum that ranges from asymptomatic infection to severe cholera known as *cholera gravis*. The number of asymptomatic cases that play a role in the transmission of cholera varies according to age and the endemic nature of the disease. In countries such as Bangladesh, asymptomatic cases may represent roughly half of all cases (Nelson et al. 2009).

Although cholera has been a localized phenomenon in South Asia for centuries, the pathogen has repeatedly demonstrated the ability to spread both regionally and internationally. The seventh worldwide pandemic of cholera began in 1961 and is ongoing. The control of the disease requires a combination of interventions that range from water supply and sanitation improvements at the community level to the use of currently available oral cholera vaccines at the individual level.

1.5 Cholera in Haiti

In October 2010, cholera appeared in Haiti. At the beginning of the outbreak, the source of the 2010 outbreak was a topic of debate. Three credible hypotheses were proposed. The first hypothesis held that an environmental strain of *V. cholerae* that normally inhabits the Gulf of Mexico traveled to Haiti naturally via ocean currents as a consequence of the January 12th, 2010 earthquake and caused the present cholera epidemic. The second hypothesis held that a local, non-toxigenic *V. cholerae* strain endemic to the Haitian environment naturally mutated into a virulent pathogenic strain, which quickly spread throughout the human population of Haiti. The third hypothesis held that the source of the outbreak was an infected human who carried a pathogenic strain of *V. cholerae* into Haiti from a cholera endemic region outside the country.

1.6 MINUSTAH in Haiti

The United Nations Stabilization Mission in Haiti (MINUSTAH) was created in April 2004 by the United Nations Security Council. After the January 12th, 2010 earthquake, the United Nations (UN) Security Council passed additional resolutions increasing the number of MINUSTAH forces in order to support recovery, reconstruction, and stability efforts. A specific form of the third hypothesis for the source of the cholera outbreak, that soldiers at the Mirebalais MINUSTAH camp were the direct source for the cholera outbreak, was a commonly held belief in Haiti immediately after the introduction of cholera. Testimony cited to support this belief includes the following: (1) the Mirebalais MINUSTAH camp is located near the area where the first cholera cases were identified; (2) a new group of soldiers had recently arrived at the time of the first cases; and (3) witnesses reported sanitation practices at the camp that allowed soldiers' feces to enter the environment.

1.7 Convening of Independent Panel

In order to definitively determine the source of the outbreak, the Secretary-General of the UN convened the Independent Panel of Experts on the Cholera Outbreak in Haiti (the "Independent Panel"), with the mandate to "investigate and seek to determine the source of the 2010 cholera outbreak in Haiti", and to present the findings of this investigation in a written report submitted to the UN Secretary-General and to the Government of Haiti.

Before convening the Independent Panel, a definitive determination of the source of the 2010 cholera outbreak in Haiti had been lacking. Two previous investigations that commented on the source of the outbreak came to opposing conclusions: Sack (Hurtado 2010 and personal communication) concluded that the outbreak was caused by a local event; whereas Piarroux (2010 and personal communication) concluded that the outbreak was caused by cholera being imported to Haiti by an infected MINUSTAH soldier. Neither investigation presented sufficient evidence to support its conclusions with absolute certainty at the time of the Independent Panel's convening.

The four members of the Panel were selected for their various areas of expertise, including microbiological (Balakrish Nair), epidemiological (Claudio Lanata), cholera (Alejandro Cravioto), and water and sanitation (Daniele Lantagne). To conduct the investigation the Panel members: (1) conducted meetings in Asia and the United States with key informants; (2) convened for field investigations in Haiti from February 14–18, 2011; (3) conducted further meetings in the United States with key informants; (4) convened in March 2011 to draft the report; and (5) convened in May 2011 to finalize the report and present the results to the Secretary-General. A copy of the finalized report was presented to the UN Secretary-General's office the evening before the formal meeting with the Secretary-General (Cravioto et al. 2011),

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and later adopted for peer-reviewed publication (Lantagne et al. 2012). All informants and documentation received relevant to the investigation were kept confidential and not provided to the Secretary-General's office.

2 Results of the Report of the Independent Panel

To determine the source of the 2010 Haiti cholera outbreak, the Independent Panel undertook concurrent epidemiological, water and sanitation, and molecular analysis investigations. Epidemiological information was obtained from records of diarrheal illnesses among MINUSTAH personnel, as well as during visits to hospitals along the Artibonite River to determine the exact onset dates of the cholera outbreak throughout the watershed. Discussions were held with local experts to understand the hydrology of the Artibonite River and its tributaries, the water and sanitation situation in the Mirebalais MINUSTAH camp, and water use practices of the population along the river. Published and unpublished information was obtained from groups currently working on the evolution of *V. cholerae* in Haiti and worldwide. Information on the basic microbiology and data from advanced molecular typing techniques was used to compare the Haitian strains against other known worldwide strains of *V. cholerae*. Each of these three investigations will be described in the following sections.

2.1 Epidemiological Investigation

MINUSTAH uniformed personnel in Haiti originate from 22 countries, and are deployed in contingents based on their country-of-origin to specific geographical areas in Haiti. In Centre and Artibonite Departments, there were permanently deployed contingents from Nepal, Argentina, and Peru. Contingents from Nepal were stationed in three camps (Hinche, Mirebalais, and Terre Rouge).

MINUSTAH contingents are deployed in 6 month rotations. The replacement Nepal contingent arrived in Centre Department between October 8th and 24th, 2010 after 3 months of training in Kathmandu, Nepal. Once the training and a medical examination were completed, soldiers were given a 10 day free period to visit their families before traveling to Haiti. Within 1 day of arrival in Haiti, soldiers were transported to their posts in Centre Department.

The medical records of MINUSTAH personnel stationed in Haiti for the time period between September and October 2010 were obtained and reviewed. No cases of severe diarrhea and dehydration occurred among MINUSTAH personnel during this period.

In each hospital visited along the Artibonite River, a detailed review of medical records from October 2010 was carried out to identify cases, especially adults, that required hospitalization due to diarrhea and dehydration in order to establish an

outbreak onset date. Since detailed medical records did not exist, which would have allowed an epidemiological definition of a cholera case to be created, hospitalizations due to severe diarrhea were used as a proxy for cholera cases.

At Mirebalais Government Hospital in Mirebalais, the first severe diarrhea case that required hospitalization and the first death from dehydration in patients older than 20 years of age occurred during the night of October 17th, 2010 and early morning of October 18th, 2010, respectively. No fish or shellfish products from the coast were found in the Mirebalais market by the Independent Panel. At Hospital Albert Schweitzer, two-thirds of the way between Mirebalais and St. Marc, the first cases of severe diarrhea requiring observation and hospitalization were seen on October 20th, 2010. At St. Nicolas Hospital in St. Marc in the Artibonite River Delta, a low background rate of diarrhea was abruptly interrupted by an explosive outbreak of cholera cases with dehydration and death on October 20th, 2010. On this date, medical staff recorded 404 hospitalizations (one every 3.6 min) and 44 deaths on individual pieces of paper. These 404 cases came from 50 identified communities throughout the Artibonite River Delta region, with only 9 (2.2 %) of the 404 patients originated from St. Marc. It is important to mention that cholera cots, designed to minimize fecal contamination in cholera wards and to measure fluid loss easily, were not seen in any of the three hospitals visited.

2.2 Water and Sanitation Investigation

The Artibonite River is the largest river in Haiti, flowing from the mountains of the Dominican Republic to the coast near the town of Grande Saline (Fig. 1). The river is controlled at two points: (1) the Peligre Hydroelectric Dam, which is located approximately 10 km upstream from Mirebalais and is operated by Électricité d'Haïti (EDH); and (2) at the Canneau Canal Site where the river is split into a series of canals for use by small farmers to irrigate their fields in the Artibonite Valley.

At the Peligre Dam, EDH engineering staff reported that it takes 1.5–2 days for water released from the dam to reach the Canneau Canal Site. At the Canneau Canal Site, operations and maintenance staff also reported that water flows from the Peligre Dam to Canneau in 2 days. In St. Marc, Artibonite Valley engineering staff reported that it takes about 1 day for water to flow from the Peligre Dam to the Canneau Canal Site, and another 1 day for water to flow from Canneau through the canal system to the sea in the Artibonite River Delta.

Two branches of the Meye Tributary of the Artibonite River flow northwards from the mountains that are located to the southwest and southeast of Mirebalais (Fig. 1). The branches join together to form the Meye Tributary just north of the Mirebalais MINUSTAH camp. There is significant human activity along this tributary, with women washing, people bathing, people collecting water for drinking, and children playing.

At the time of the Independent Panel's visit, there was one main area at the Mirebalais MINUSTAH camp that housed toilet and showering facilities for the

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Fig. 1 Sites visited along Artibonite River

contingent. Gray water waste (cooking water, wash water, shower water) flowed into on-site soak pits and was allowed to drain into the soil. Black water waste (containing human feces) flowed into six 2,500 l fiberglass tanks. The construction of the water pipes in the main toilet/showering area was haphazard, with significant potential for cross-contamination through leakage from broken pipes and poor pipe connections, especially from pipes that ran over an open drainage ditch that runs throughout the camp and flows directly into the Meye Tributary System (Fig. 2). It was evident from inspection, as well as reported by local Haitians, that construction work in this area had been undertaken after October 2011.

The black water tanks were emptied on demand by a contracting company approved by MINUSTAH headquarters in Port-au-Prince. The contracting company dispatched a truck from Port-au-Prince to collect and transport the waste across the



Fig. 2 Toilet area and canal flowing into Meye Tributary

Fig. 3 The black water disposal pit



street and up a residential dirt road to a location at the top of the hill, where the waste was deposited in an open septic pit (Fig. 3). Black water waste for the two other MINUSTAH facilities—Hinche and Terre Rouge—was also disposed of in this pit. There was no fence around the site, and children were observed playing and animals roaming in the area around the pit. The southeast branch of Meye Tributary System is located a short walk down the hill from the pit, and local residents reported the area is susceptible to flooding and overflow into the Tributary during rainfall. Calculations indicate that it would take 2–8 h for water to flow from near the septic disposal pit to the junction with the Artibonite River.

2.3 Molecular Analysis Investigation

At the time of the Independent Panel's investigation, the current Nepal strain of cholera was not available for molecular analysis. Thus, the Independent Panel was able to review information on the Haitian strain itself, and on comparing the Haitian strain to other known strains. The available molecular data from whole genome sequence and smaller comparisons of specific parts of the genomes of the *V. cholerae* strains responsible for the outbreak of cholera in Haiti showed a remarkable consistency. They all indicated that the Haitian strains were: (1) clonal (genetically identical) indicating a point-source for the outbreak; and (2) very similar but not identical to the South Asian strains of *V. cholerae* O1. It was emphasized, however, that the Haitian strains has certain minor traits not found in collections from across the world, which is consistent with the micro-evolution that takes place continuously within the El Tor biotype as it moves throughout the world.

Our analysis of available data at the time of our investigation refuted the argument that the Haitian strains arose indigenously from the Haitian environment. The Haitian strains did not originate from the native environs of Haiti but as a result of human activity in an area that promoted the dissemination of the organism. The presence of riverine settings that merges into an estuarine environment, which is an optimal setting for rapid growth of *V. cholerae* O1, is likely to have contributed to the rapid spread of the pathogen. This has happened before in many parts of the world. The precise country from where the Haiti isolate of *V. cholerae* O1 arrived is debatable. Such a conclusion, if warranted, can only be made if representative strains from other countries in South Asia were available for global DNA sequence comparisons. Since none of these stains from Nepal were available for comparison at the time of the preparation of our report it was not possible to established a direct comparison between strains of *V. cholerae* O1 circulating in Nepal strains and those circulating in Haiti.

2.4 Results

The epidemiological data indicated the cholera epidemic began in the upstream region of the Artibonite River on October 17th, 2010. As this region has little to no consumption of fish or shellfish products, the most likely cause of the outbreak was the consumption of contaminated water from the river. Two to three days later, an explosive cholera outbreak began on October 20th, 2010 in the Artibonite River Delta.

The sanitation conditions at the Mirebalais MINUSTAH camp were not sufficient to prevent contamination of the Meye Tributary System with human fecal waste. Contamination in the Meye could have reached Canneau within 1–2 days, and would have been fully distributed in the canal system in the Artibonite River Delta within a maximum of 2–3 days, consistent with the epidemiological timeline.

The available molecular data from whole genome sequence and comparisons of smaller specific parts of the genomes of the *V. cholerae* strains responsible for the outbreak of cholera in Haiti all indicate that the Haitian strains are: (1) clonal (genetically identical) indicating a point-source for the outbreak; and, (2) very similar but not identical to the South Asian strains of *V. cholerae* O1. The precise country from where the Haiti isolate of *V. cholerae* O1 arrived is unknown.

2.5 Conclusions

At the time of the report, the evidence did not support the hypotheses suggesting that the current outbreak is of a natural environmental source. In particular, the outbreak was not due to the Gulf of Mexico strain of *V. cholerae*, nor was it due to a pathogenic mutation of a strain indigenously originating from the Haitian environment. Instead, the evidence overwhelmingly supported the conclusion that the source of the Haiti cholera outbreak was due to contamination of the Meye Tributary of the Artibonite River with a pathogenic strain of current South Asian type *V. cholerae* as a result of human activity.

This contamination initiated an explosive cholera outbreak downstream in the Artibonite River Delta, and eventually, throughout Haiti. The explosive spread was due to several factors:

- Tens of thousands of Haitians use the Meye Tributary System and Artibonite River waters for washing, bathing, drinking, and recreation, and were thus exposed to cholera;
- Thousands of Haitian agriculture workers are regularly exposed to the Artibonite River water, particularly in the rice paddy fields;
- The canal system and delta of the Artibonite River provided optimal environmental conditions for rapid proliferation of *V. cholerae*;
- The Haitian population lacked immunity to cholera;
- Many areas of Haiti suffer from poor water and sanitation conditions;
- Infected individuals fled to their home communities from the initial outbreak locations, and in the process dispersed the disease;
- Infected individuals rapidly concentrated where treatment was available;
- The South Asian type *V. cholerae* strain that caused the outbreak causes a more severe diarrhea due to an increase in the production of a classical type of CT and has the propensity of protracting outbreaks of cholera; and
- The conditions in which cholera patients were initially treated in medical facilities did not help in the prevention of the spread of the disease to other patients or to the health workers.

The introduction of this cholera strain as a result of environmental contamination with feces could not have been the source of such an outbreak without simultaneous water and sanitation and health care system deficiencies. These

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deficiencies, coupled with conducive environmental and epidemiological conditions, allowed the spread of the *V. cholerae* organism in the environment, from which a large number of people became infected. The Independent Panel concluded that the Haiti cholera outbreak was caused by the confluence of circumstances as described above, and was not the fault of, or deliberate action of, a group or individual.

The source of cholera in Haiti is no longer relevant to controlling the outbreak. What are needed at this time are measures to prevent the disease from becoming endemic.

2.6 Recommendations

The Independent Panel of Experts on the Cholera Outbreak in Haiti made the following recommendations to the UN, the Government of Haiti, and the international community:

- The Haiti cholera outbreak highlights the risk of transmitting cholera during mobilization of population for emergency response. To prevent introduction of cholera into non-endemic countries, United Nations personnel and emergency responders traveling from cholera endemic areas should either receive a prophylactic dose of appropriate antibiotics before departure or be screened with a sensitive method to confirm absence of asymptomatic carriage of *V. cholerae*, or both.
- UN missions commonly operate in emergencies with concurrent cholera epidemics. All UN personnel and emergency responders traveling to emergencies should receive prophylactic antibiotics, be immunized against cholera with currently available oral vaccines, or both, in order to protect their own health and to protect the health of others.
- To prevent introduction of contamination into the local environment, UN installations worldwide should treat fecal waste using on-site systems that inactivate pathogens before disposal. These systems should be operated and maintained by trained, qualified UN staff or by local providers with adequate UN oversight.
- To improve case management and decrease the cholera case fatality rate, UN agencies should take stewardship in:
 - Training health workers, especially at the treatment center level;
 - Scaling-up the availability and use of oral rehydration salts at the household and community level in order to prevent deaths before arrival at treatment centers; and
 - Implementing appropriate measures (including the use of cholera cots) to reduce the risk of intra-facility transmission of cholera to health staff, relatives, and other patients.

- To prevent the spread of cholera, the UN and the Government of Haiti should prioritize investment in piped, treated drinking water supplies, and improved sanitation throughout Haiti. Until such time as water supply and sanitation infrastructure is established:
 - Programs to treat water at the household or community level with chlorine or other effective systems, handwashing with soap, and safe disposal of fecal waste should be developed and/or expanded; and
 - Safe drinking water supplies should continue to be delivered and fecal waste should be collected and safely disposed of in areas of high population density, such as the spontaneous settlement camps.
- The international community should investigate the potential for using vaccines reactively after the onset of an outbreak to reduce cholera caseload and spread of the disease.
- Recent advances in molecular microbial techniques contributed significantly to the investigative capabilities of this report. Through its agencies, the UN should promote the use of molecular microbial techniques to improve surveillance, detection, and tracking of *V. cholerae*, as well as other disease-causing organisms that have the potential to spread internationally.

3 Responses to Report

The immediate response to the report of the UN was to establish a Task Force to evaluate the recommendations and state that the report “does not present any conclusive scientific evidence linking the outbreak to the MINUSTAH peacekeepers or the Mirebalais camp” and “anyone carrying the relevant strain of the disease in the area could have introduced the bacteria into the river” (Reuters 2011; UN News Centre 2011). The Task Force did submit one request for additional information from the Independent Panel, which was answered. To date, no further contact has been initiated, and no results from the Task Force released.

The immediate press response to the Independent Panel’s report was a fascinating perspective on how science is translated to the public through media. As members of the Independent Panel we knew we were writing an important, political report that would be scrutinized closely. We made a group decision we would write the report in scientific language, speaking as experts in the field, reporting what we could with scientific certainty. All text was reviewed and approved by all members of the Independent Panel, and key text—including the Executive Summary, Conclusions, and Recommendations—were written as a consensus-based verbal process, with a recorder writing the language, which was then reviewed by all.

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The immediate media response focused around the key theme of blame, and whether, and to whom, the panel apportioned blame to, including some representative samples below:

- But the four scientific experts refrained from blaming UN peacekeepers ... Instead their report said the outbreak was a result of a “confluence of circumstances” (Leopold 2011).
- But—perhaps so as not to fan the flames—it stops short of blaming the Nepalese or MINUSTAH. Instead, the report stresses that the disease became a major disaster as a result of a series of circumstances, including Haiti’s poor drinking water and sanitation infrastructure and lack of medical services. The outbreak “was not the fault of, or deliberate action of, a group or individual,” it says (Enserink 2011).
- The 32-page report ... clearly states that the source of the epidemic was most likely a camp for UN peacekeepers in Haiti, whose human waste was dumped by independent contractors into an unsecured pit that was susceptible to flooding in heavy rainfall. But the report buries that central finding under a welter of circumstances that caused investigators to conclude that the outbreak, which is ongoing, “was not the fault of, or deliberate action of, a group or individual” (Russell 2011).
- Fortunately, most news articles have looked beyond the conclusion of the report, and accurately noted that while the panel members refused to lay blame on MINUSTAH, the evidence in the report clearly does. As Joe Lauria of the Wall Street Journal wrote: The report plays down as a “hypothesis that soldiers deployed from a cholera-endemic country to the Mirebalais Minustah camp were the source of the cholera” which it said was “a commonly held belief in Haiti.” But the report then describes in detail how the outbreak occurred because of contamination of the Artibonite River from the peacekeeping camp (CEPR 2011).
- But the panel refused to single out the troops for blame, stating that Haitians—who had recently suffered a devastating earthquake—should not have been using the river for drinking or washing (Lynn 2011).
- It is also a masterpiece of diplomatic writing that never once directly names the Nepali peacekeepers as the carriers of the South Asian strain of *V. cholera* that has killed almost 5,000 persons and sickened a quarter of a million. In fact, the report blames the victims much more directly (Crof 2011).

The comments above can be summarized into questions on: 1) Why did we not blame the Nepali MINUSTAH soldiers? 2) Why did we not blame the United Nations? and 3) Why did we blame the Haitians?

There are two answers to the first question. First, the majority of the evidence presented in the report was circumstantial. As we did not have microbiological evidence to support a direct link between the Nepal and Haiti strain at the time of writing, we did not feel we could present with scientific certainty that someone associated with the MINUSTAH facility was responsible for the introduction of cholera into Haiti. As the United Nations stated, it could, theoretically, have been

someone else infected with that strain in the same area, however unlikely that might be. Second, we strongly felt that the introduction of cholera into Haiti was an accidental, as opposed to a deliberate, act. Thus, whomever—whether it be a peacekeeper or another individual—introduced the strain should not be held personally responsible.

To answer the second questions, we felt the transmission of cholera in this manner was so unprecedented and unlikely, as evidenced by the CDC statement, that we did not feel that this was a predictable event. While we know now that cholera can be introduced in this manner, and thus should strive to prevent this happening in the future, at the time of the report, this was a novel thought.

For the third question, we do not feel we blamed the Haitians for the outbreak. To cause an outbreak you need a source, a means of dissemination, and a susceptible population. Haiti, sadly, had all three, and the confluence of all three is what led to the outbreak.

Some journalists, in our opinion, translated the scientific language into popular media accurately, such as the Independent: “An official report into the ongoing epidemic, which began last October, has concluded that it was almost certainly caused by a poorly constructed sanitation system installed at a rural camp used by several hundred UN troops from Nepal” (Adams 2011).

On the whole, the media response caused us to reflect on the role of writing for scientific certainty in situations with imperfect information.

4 Additional Evidence and Response

Since the completion of the Independent Panel’s report, there has been a plethora of research on the Haitian cholera outbreak. In total, the weight of this additional evidence supports the conclusions of the Independent Panel. Three articles in particular expand upon our conclusions. On August 23, 2011, results from whole-genome sequence typing to compare Nepal 2010 cholera strains to the Haiti cholera strain were reported; the authors found that “three Nepalese isolates and three Haitian isolates that were almost identical, with only 1- or 2-bp [base-pair] differences. Results in this study are consistent with Nepal as the origin of the Haitian outbreak.” (Hendriksen et al. 2011). In July 2011, results from an epidemiological investigation conducted by a French and Haitian team in December 2010 were published, with their epidemiological model “strongly suggest[ing] that contamination of the Artibonite and one of its tributaries downstream from a military camp triggered the epidemic” (Piarroux et al. 2011). Finally, staff of the non-governmental organization Partners in Health used qualitative methods including community focus groups, discussions with key local leaders, and their extensive local community health worker network to identify the “first” case of cholera in Haiti—a mentally ill man who lived downstream of the MINUSTAH facility, often drank and bathed in the Meye tributary waters, developed cholera on October 12, 2010, and subsequently died in his home (Ivers and Walton 2012).

The weight of this additional evidence has led to significant pressure on the UN. The BBC, the New York Times, and al Jazeera have all run high profile stories on the topic of the introduction of cholera in Haiti (Doyle 2012; Salomey 2012; Sontag 2012). In November 2011, the BAI [Bureau des Avocats Internationaux] and IJDH [Institute for Justice and Democracy in Haiti] filed a case against the UN on behalf of 5,000 Haitian cholera victims demanding that the UN: (1) install a national water and sanitation system; (2) compensate individual victims of cholera for their losses; and (3) issue a public apology from the UN (IJDH 2013). In December 2011, the UN Office of Legal Affairs acknowledged receipt and said they would reply “in due course”. On February 21, 2013, the UN did reply, stating the claim was “not receivable” because of the diplomatic immunity of the UN (Ivers 2013).

The response of the UN to date has been not to focus on the legal issues of the introduction of cholera, but instead to state “my focus is on today, as it has been since the outbreak, and is on making sure that Haitians stay alive” (Olson 2012). On December 11, 2010, the U.N. Secretary-General Ban Ki-moon announced a \$2.27 billion initiative to eradicate cholera in Haiti and the Dominican Republic, and vowed to work aggressively to secure donations for the ambitious but largely unfunded 10-year plan that focuses on water and sanitation infrastructure development and vaccine distribution (UN News Centre 2013).

It is not clear at this point in time how successful water and infrastructure development and vaccination campaigns in Haiti can be in preventing the transmission of cholera, even if the mandate is funded. Political will and capacity building will be required to support the development of sustainable water and sanitation infrastructure. On March 16, 2010, the World Health Organization (WHO) revised an April 2001 position paper on the use of vaccines in response to cholera (WHO 2010). In the new Position Paper, the WHO reiterates the need for the “mainstay of control measures”—cholera case control, water and sanitation interventions, and community mobilization; but also states: “Given the availability of two oral cholera vaccines and data on their efficacy, field effectiveness, feasibility and acceptance in cholera-affected populations, immunization with these vaccines should be used in conjunction with other prevention and control strategies in areas where the disease is endemic and should be considered in areas at risk for outbreaks. Vaccination should not disrupt the provision of other high-priority health interventions to control or prevent cholera outbreaks. Vaccines provide a short-term effect that can be implemented to bring about an immediate response while the longer term interventions of improving water and sanitation, which involve large investments, are put into place.” In Haiti, Partners in Health distributed 45,000 vaccines in cholera-endemic high-risk rice farming villages near the Artibonite Delta (PIH 2013). A positive public health outcome was that 90 % of those vaccinated received both required doses, however as of this writing, there has been no impact evaluation conducted on the program.

Overcoming the weight of history to establish programs to reduce the burden of cholera to the population of Haiti will be both a challenging and necessary endeavor.

5 Current Statement on the Source of Cholera in Haiti

The exact source of introduction of cholera into Haiti will never be known with scientific certainty, as it is not possible to travel back in time to conduct the necessary investigations, and those on the ground at the time focused on outbreak response not source introduction. However, the preponderance of the evidence and the weight of the circumstantial evidence does lead to the conclusion that personnel associated with the Mirebalais MINUSTAH facility were the most likely source of introduction of cholera into Haiti. We would like to highlight here that we do not feel that this was a deliberate introduction of cholera into Haiti; based on the evidence we feel that the introduction of cholera was an accidental and unfortunate confluence of events. Action should be taken in the future to prevent such introduction of cholera into non-endemic countries in the future.

6 Public Health Implication

As of December 2012, the cholera outbreak in Haiti continues. The partners involved in cholera response have reduced the mortality rates by treating the symptoms and launching an awareness campaign. However, as of March 13, 2013, there still have been 650,218 cases of cholera reported, and 8,048 deaths (MSPP 2013). In 2011, Haiti accounted for 340,311 of 589,534 (57.7 %) of reported cholera cases worldwide (WHO 2012). Although the case number has declined in 2012, the capacity to respond to the epidemic has also decreased, as in December 2010, 61 cholera treatment centers were operational, compared to only 20 in December 2012 (OCHA 2013b). At this point in time, Haiti continues to work to recover from the January 2010 earthquake, the October 2010 introduction of cholera, new natural disasters such as Hurricane Thomas and Hurricane Sandy, and ongoing political instability. It is a challenging road ahead.

Lastly, the use of concurrent epidemiological, water and sanitation, and molecular analyses was a powerful combination in our investigation to identify and verify the source of the outbreak almost 6 months after outbreak initiation. While it was not possible to identify the exact individual(s) who transported the bacteria into Haiti, the use of the concurrent investigations allowed us to: (1) pinpoint and verify the outbreaks' geographical origin and transmission route; (2) determine the most likely source of introduction; and (3) make recommendations to prevent such introduction in the future. Concurrent analyses are recommended to public health professionals for future cholera investigations.

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The Cholera Outbreak in Haiti: Where and how did it begin?

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