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Perspective

The 1991 Cholera Epidemic in Peru: Not a Case of Precaution Gone Awry

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The precautionary principle calls on decisionmakers to take preventive action in light of evidence indicating that there is a potential for harm to public health and the environment, even though the nature and magnitude of harm are not fully understood scientifically. Critics of the precautionary principle frequently argue that unbridled application of the principle leads to unintended damage to health and ecosystems (risk tradeoffs) and that precautious decision making leaves us vulnerable to "false-positive" risks that divert resources away from "real risks." The 1991 cholera epidemic in Peru is often cited as an example of these pitfalls of the precautionary principle. It has been mistakenly argued that application of the precautionary principle caused decisionmakers to stop chlorinating the water supply due to the risks of disinfection byproducts (DBPs), resulting in the epidemic. Through analyses of investigations conducted in the cities of Iquitos and Trujillo, Peru, literature review, and interviews with leading Peruvian infectious disease researchers, we determined that the epidemic was caused by a much more complex set of circumstances, including poor sanitation conditions, poor separation of water and waste streams, and inadequate water treatment and distribution systems. The evidence indicates that no decision was made to stop chlorinating on the basis of DBP concerns and that concerns raised about DBPs masked more important factors limiting expansion of chlorination. In fact, outside of Peru's capital Lima, chlorination of drinking water supplies at the time of the epidemic was limited at best. We conclude that the Peruvian cholera epidemic was not caused by a failure of precaution but rather by an inadequate public health infrastructure unable to control a known risk: that of microbial contamination of water supplies.

KEY WORDS: Cholera; Peru; precautionary principle; risk tradeoffs; water disinfection

1. INTRODUCTION

The precautionary principle calls on decisionmakers to take preventive action when evidence indicates that there may be a potential for harm to public health and the environment, even though the nature and magnitude of the harm are not fully understood scientifically. Taking a cautious approach to managing uncertain environmental risks requires (1) examining risks and benefits of a wide range of alternative approaches to meeting a particular social need; (2) shifting the responsibility for documenting the risks of and alternatives to a technology from government agencies to those who stand to benefit from that technology; and (3) involving the communities that will be affected by any decision to act or not act.[(1)]

Critics of the precautionary principle frequently claim that the principle is anti-science. We have responded to this claim elsewhere by arguing that

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the precautionary principle calls for expanded scientific tools for the characterization and prevention of complex risks.[2,3] These same critics also argue that applying the precautionary principle in real-life situations leads to unintended damage to health and ecosystems, known as risk tradeoffs, as well as false positives, where decision making is based on unwarranted fears or unnecessary alarms.[4] A risk tradeoff occurs when action to control one risk inadvertently results in the creation of a new and potentially more problematic risk; and a false positive occurs when an exposure appears to increase risk, when in fact the two are not related.

In this commentary, we present a case study of an often cited example of how the precautionary principle can result in risk tradeoffs with adverse health consequences: the 1991 cholera epidemic in Peru. In late January 1991, *Vibrio cholerae* was identified among patients presenting at northern Peruvian coastal hospitals. By the end of 1991, over 300,000 cases of cholera were identified, though surprisingly, the mortality rate resulting from cholera-induced dehydration was less than 1% due to the rapid interventions undertaken by the Peruvian public health community.[5–8] The epidemic quickly spread to neighboring Brazil, Colombia, Ecuador, and further up the coast to Guatemala, Panama, and Mexico, resulting in more than 1.3 million cases of cholera in the years 1991–1995.[6,7] While consumption of raw seafood was originally suspected as the vehicle for the transmission of cholera, contaminated drinking water was an important factor in the rapid dissemination of the disease.[5]

Miller and Conko,[9] among others, have argued that the Peruvian government stopped chlorinating drinking water supplies in the country following the publication of U.S. EPA reports on the health risks of disinfection byproducts (DBPs), out of concern for this newly recognized hazard.[10] A 2004 commentary by C. T. Howlett, Director of the U.S. Chlorine Chemistry Council, summarizes this argument: "In Peru, in the early 1990s public health officials responded to an antichlorine campaign by stopping proper chlorination of their drinking water. The results were predictable and horrific. Within months, a cholera epidemic swept through the country, eventually causing 1.3 million cases of illness and 13,000 deaths."[11] The main source for this assertion is a single-page 1991 news article in the journal *Nature*.[12] The epidemic has been cited as an example of how "implementation of the precautionary principle is often hazardous because it draws the attention of consumers and policymaker from known, significant dangers to human health and diverts public health resources from the handling of such dangers."[9]

Analyses by the EPA and others have found that DBPs, most notably trihalomethanes, do present uncertain, though real, human cancer and reproductive risks.[13,14] Thus effective chlorination of drinking water, while reducing substantially the risk of cholera, may increase cancer or reproductive health risks. In countries such as Peru, where cholera and other infectious diseases remain a real threat, it would seem prudent to accept a small cancer risk as an unfortunate consequence of an effective method of preventing cholera, although in the long term, the risk tradeoff might also stimulate a search for safer means of disinfecting drinking water. But the question we investigated is: Did concern for the risks from DBPs in any way contribute to the cholera epidemic of 1991? If so, then we might conclude that the case illustrates a serious unintended consequence of a "precautionary" effort to avoid DBP risks.

Through literature reviews, interviews with Peruvian and U.S. experts, and an examination of the evolution of the epidemic in two cities, Trujillo and Iquitos, we examine three key questions: (1) Was there a decision to stop chlorinating Peru's water supplies as a result of concern over DBPs? (2) Did this decision result in the 1991 Peruvian cholera epidemic? and (3) Was this a failure of the precautionary principle?

We argue in this article that the Peruvian cholera epidemic was caused by a much more complex set of circumstances that were unrelated to concerns over the uncertain health risks caused by exposure to DBPs. Financial and administrative difficulties, outdated and inadequate water treatment equipment and pipes, unsanitary water storage conditions, consumption of contaminated food, and lack of adequate sewage disposal are a few of the important factors that contributed to the spread of cholera in Peru. Indeed, the evidence indicates that there never was a decision to "stop" chlorinating the drinking water. In addition to infrastructure limitations, events outside of Peruvian control, such as dumping of cholera-contaminated bilge and global change, may have helped advance the reintroduction of cholera to Peru after a century of living cholera free.[15]

2. EXAMPLE OF INADEQUATE INFRASTRUCTURE: TRUJILLO, PERU

Salzar-Lindo and colleagues conducted an investigation of the water supply and cholera epidemic in Trujillo, Peru's third largest city.[5] Prior to the cholera epidemic, the city's drinking water came from 43 wells dug approximately 60 feet into the ground. Trujillo's engineers in charge of the system believed that the water was pristine and thus there was no need to chlorinate, particularly given concerns about risks from DBPs. However, they failed to account for the fact that 35% of the city's water was supplied by public standpipes (water access points), or by tanker trucks, using city water.[5,16] These distribution methods could result in unintended contamination of drinking water during storage.

Despite the decision not to chlorinate, the sanitary conditions under which water was obtained and stored offered insufficient protection from waterborne diseases such as cholera. In particular, the water distribution system was vulnerable to contamination as a result of clandestine taps in the pipes, leaks due to inadequate and irregular maintenance, electrical outages that shut off water pumps, and postdistribution contamination during storage.[5,17]

2.1. Poor Sanitary Conditions of Water Access

Approximately 143,325 people obtained drinking water from standpipes, clandestine breaks, or tanker trucks.[5] Those without in-home tap access typically stored water in inadequately covered barrels outside their homes. Smaller bucketfuls and cupfuls of water were brought into the home on a daily basis by submerging hands and arms into the water. Those with access to running tap water also stored water in barrels as a back-up source for those times when water service was not available, as water was provided to the system for only approximately 14 hours per day. Households at a greater distance from the central system could rely on running water for only 1 to 2 hours per day.[5,16]

In one study, researchers determined that water samples taken from storage barrels had the greatest number of total and fecal coliform counts (an indication of contamination) while water taken from wells and from the distribution pipes had lower counts.[16] This suggests that water generally became contaminated while being stored in barrels. In addition to the potential for water to become contaminated from inadequately covered barrels, pathogens, bacteria, and dust could contaminate water when residents' unclean hands and arms were plunged into the barrel during water retrieval, exposing others to cholera.[16] Stored contaminated water was found to be a major source of cholera transmission in research conducted by Salzar-Lindo *et al.*[5] They found a cholera attack rate more than one and a half times higher among those whose primary water source was tanker trucks (3.14%) compared to those who primarily accessed water through an in-home tap (1.97%).[5]

2.2. Inadequacies in the Water Distribution System

It appears that Trujillo's engineers in charge of the drinking water system did not consider the effect that the old, poorly maintained, and illegally tapped distribution pipes (where as much of 40% of the city's water supply was being lost) could have on the system as a whole.[5,17] Many of the pipes were installed in the 1950s and had not been updated.[5] Leaks were not always properly repaired. Due to frequent water shortages, clandestine taps were an important problem. It became a practice for residents to locate a water pipe, make a crack or a hole in the line so that water could be drained into buckets, and then reseal the holes with pieces of paper wrapped in plastic.[5,16] These leaks and illegal taps allowed untreated sewage and microorganisms to enter the system, thus contaminating water.[5,17]

In addition, researchers noted that the Trujillo system was not operable an average of 10 hours per day because electrical outages prevented the pumps from running. When water does not flow continually through the pipes, inadequate levels of water pressure are maintained. Inadequate water flow allows unsafe water and microorganisms to seep into the system from the holes (from clandestine breaks), leaks, and cracks in the pipes, thus exposing residents to dangerous bacteria and pathogens.[5,17]

2.3. Actions Taken to Address the Problem

Almost immediately after the cholera outbreak began in February 1991, chlorination was initiated in Trujillo's water supply. However, efforts to fix the deteriorating water distribution system as well as monitoring for fecal coliforms and residual chlorine (to examine the efficacy of the water treatment system) were not undertaken. Despite chlorination and aggressive national educational efforts to encourage home disinfection of drinking water through boiling, bleach, and chlorine tablets (only partially effective because of high energy costs and difficulties in distribution of chlorine tablets), cholera returned to Trujillo in the summer of 1992, albeit resulting in about one-quarter the number of cases as in 1991. This suggests that contamination of the water supply persisted, though disinfection efforts were successful in reducing the number of cases.[5]

3. EXAMPLE OF POOR SANITATION PRACTICES: IQUITOS, PERU

Iquitos, Peru is a city of 285,000 people located in the Amazon jungle. The primary drinking water source in Iquitos was a nearby river, from which water was pumped to the city. Residents of Iquitos accessed drinking water from in-home taps (50%), public standpipes or shallow wells (33%), and directly from the river (18%).[5] Chlorination was used to treat water distributed through in-home taps and standpipes. However, as in many parts of Peru, the water disinfection and distribution system of Iquitos faced particular vulnerabilities, including inadequate settling, filtering, and chlorination, as well as leaks and electrical outages that unexpectedly turned-off pumps that maintained water pressure in the system.[5]

3.1. Inadequacies in Water Treatment System

Water treatment in Iquitos consisted of coagulation, settling, filtration, and chlorination. Investigators found that coagulants were applied only infrequently and the settling tanks were inadequate to allow for proper settling of debris, including organic matter.[5] However, filtering of organic matter is an essential step in water treatment for pathogen removal and critical for disinfection with chlorine to be effective.[17] Filtering had not been conducted for some time due to the lack of proper filters.

Chlorine was applied manually and intermittently in Iquitos.[5] Water testing for residual chlorine and bacterial contamination also was not conducted regularly.[5] If done consistently, water testing results might have signaled to water officials that not enough chlorine was being used to maintain a residual effect needed to kill bacteria further down the distribution system. Bacteriologic water tests were also not regularly conducted, due to broken equipment, but tests conducted within months after the epidemic began revealed that water at the point of exit from the treatment plant was unsafe for drinking due to total coliform counts.[5] Such testing would have indicated the need for additional chlorination or in-home disinfection.

3.2. Inadequacies in the Water Distribution System

The design of the water distribution system was such that water was pumped directly to the pipelines, although the city is flat and the system would have operated more effectively and efficiently if water were pumped through elevated service reservoirs.[5] This design flaw caused households close to the treatment plant to have tap water 24 hours a day, while households further out had tap water only 0 to 1 hour a day. As was the case in Trujillo, lack of water in the distribution pipes allowed for infiltration of contaminated groundwater. Water was further contaminated from seepage of raw sewage due to the fact that much of Iquitos lacked sewers.[5] As in Trujillo, illegal taps in water distribution pipes were common, increasing the potential for contamination of the system.[5,17] For those accessing water from standpipes, additional contamination was likely as a result of barrel storage without further disinfection.

3.3. Poor Sanitary Conditions of Water Access

Residents of impoverished Barrio Belén, representing 18% of Iquitos residents, live in houses built on stilts at the mouth of the Itaya River, an Amazon River tributary. There were no systems for human waste disposal in Barrio Belén: thus raw sewage was dumped from houses into the river below. Residents of the area would take their drinking water directly from the Itaya River. The Hospital de Apoyo de Iquitos, which was providing care for most of the cholera cases in the city, also dumped its raw sewage into the Belén River upriver from Barrio Belen, further contaminating the river and exposing residents to cholera.[5] Approximately 60% of all cholera cases in Iquitos occurred in shanty towns, with investigators estimating that most of these cases occurred in Barrio Belén.[5]

3.4. Actions Taken to Address the Problem

Efforts to improve the Iquitos water supply system were not initiated until mid-1991 some months after the first cases of cholera in the city. While chlorination at the water treatment plant was increased, total chloroform counts were still unacceptably high in September 1991. Investigators found that the prolonged epidemic in Iquitos, which lasted continuously (though with significantly fewer cases) through 1992, was the result of the "complex and unsolved problems of the water supply system of that city and the extremely unsanitary living conditions of a large proportion of the population."[5] Given the local conditions, local health workers noted that more aggressive home-based chlorination and water boiling would have been critical in controlling the epidemic.

4. CHLORINATION IN PERU'S CAPITAL, LIMA

Anderson noted that local water officials in Lima, Peru's capital and largest city, decided to stop chlorinating many of Lima's wells based on DBP concerns.[12] However, evidence indicates that chlorination in Lima was never stopped and the city was not an epicenter of the epidemic. Peruvian researchers noted that the head of that city's water treatment works was surprised to hear about the lack of chlorination outside of that city and stated that the DBP cancer risks were of minimal concern to him compared to the necessity of providing safe drinking water.[18]

5. DISCUSSION—INCREASED CHLORINATION WOULD HAVE SIGNIFICANTLY REDUCED, BUT NOT HAVE PREVENTED OR STOPPED THE CHOLERA EPIDEMIC

The case examples of Trujillo and Iquitos illustrate the multiple causes of the 1991 cholera epidemic in Peru. An important conclusion of the researchers who examined cholera cases in Trujillo and Iquitos was that even if chlorination and other treatment methods had been widely employed, water still would have been contaminated as a result of (1) inadequately constructed and failing water treatment systems; (2) poorly maintained distribution systems with leaks and illegal taps and secondary contamination from storage; (3) inadequate waste and sewage treatment, which resulted in contamination of drinking water supplies; and (4) intermittent electricity, which resulted in limited operation of treatment systems and inadequate pressure in water distribution systems. Some contamination problems (illegal taps and leaks) could have been addressed through maintenance of an adequate disinfection residual, but others (pressure fluctuations and contamination of storage containers) would have been more difficult to address as these are problems in chlorinated systems as well. Thus, many of the factors contributing to the cholera epidemic in Iquitos, where limited chlorination did occur, would not have been completely addressed through additional chlorination.

Peruvian researchers concluded that "the findings in this study reveal that the water supply systems had not been properly built, maintained, or operated in Trujillo and Iquitos, resulting in drinking water of poor quality before the onslaught of the Peruvian cholera epidemic in early 1991. Water was either insufficiently disinfected (or not disinfected at all) before distribution or it became contaminated during distribution or storage in households.... Even if water were properly treated and disinfected before distribution, the poor conditions of the water lines, proliferation of clandestine connections, and the lack of continuous pressure in the distribution system ... would easily contaminate the water."[5]

5.1. Other Factors Influencing the 1991 Cholera Epidemic

In addition to limited infrastructure for safe water provision and waste management, several other factors may have played important roles in the 1991 epidemic, including (1) chlorine resistance of the strain of cholera implicated in the epidemic; (2) transmission of cholera through food; and (3) globalization and global climate change. These are discussed briefly.

The strain of cholera isolated from patients in Peru, *Vibrio cholerae* O1, El Tor, has been found to produce an exopolysaccaride that can make the bacteria more resistant to chlorine. In addition, it was a "rugose" colony variant, meaning that it forms clumps. Chlorine can kill the outer layers but has difficulty in penetrating the entire colony. The end result is that chlorination is much less effective than for other cholera strains.[19–21]

Even optimal chlorination could not have prevented the spread of food-borne cholera. It is believed that the epidemic began through consumption of contaminated seafood, particularly undercooked and raw seafood.[5] Shellfish and crustaceans in particular are likely to become contaminated with cholera after consuming contaminated plankton.[22] Eating food prepared with contaminated water (such as juices) as well as consumption of fruits and vegetables irrigated with contaminated water were other sources of food-borne cholera dissemination. In some parts of Trujillo, water from clandestine breaks in sewage lines was used to irrigate crops, such as cabbage, lettuce, carrots, and watermelon. The food-borne transmission of cholera is evidenced by a study that found an association between the consumption of raw or undercooked cabbage that had been irrigated with sewage water and going to a party (where contaminated foods might be served) and cholera.[16] However, most of the cases, as well as the rapid spread of cholera, can be best explained by contamination of drinking water.[5,16]

There continues to be a debate about how cholera was reintroduced to Latin America after nearly a century of living cholera free (there had been no epidemic cholera in Peru in the 20th century and this may have contributed to the lack of acquired specific immunity in the population).[6,8] There is some evidence that a vessel from Asia dumped its contaminated bilge into the harbor of Lima.[23] Researchers found that "DNA testing of the Latin American cholera strain shows that it is genetically similar—although not identical—to a cholera strain common in Bangladesh, and that this strain has been isolated in samples of ballast, bilge, and sewage from cargo ships active in the area."[23]

Finally, there is some evidence suggesting that global climate variations can affect cholera epidemics. The El Niño warming effect on ocean waters can promote plankton blooms, in which cholera bacteria can thrive, especially with high levels of sewage that provide needed nutrients to the microbes.[23–25] It is possible that *V. cholerae* lay dormant for a number of years before El Niño raised temperatures in the waters to a level at which the bacteria could be infectious to humans, particularly in Peru where the population lacked immunity to cholera.[15]

5.2. Was a Decision to Halt Chlorination Ever Made and Was That Precautionary?

It is clear from various investigations that adequate treatment and chlorination of drinking water supplies in Peru at the time of the cholera outbreak was limited at best. It is also clear from our review that no decision was made to halt chlorination as a result of concerns over DBPs. Indeed, researchers note that the government was actually encouraging water chlorination and education about drinking water contamination and good sanitation practices before, and more so, after the epidemic began. They encouraged these particularly through the use of chlorine tablets, personal hygiene (hand washing), water boiling, and aggressive postepidemic chlorination of town water supplies and hospitals.[5,18,26]

Research over the past 20 years has indicated that DBPs pose risks to human health.[13,14] Thus, concerns over DBPs cannot be considered a false positive. However, it is evident that in a country such as Peru, health risks from cholera and other water-borne pathogens and microbial risks clearly outweighed the risks from DBPs. Thus, while no decision was made to halt chlorination, the question remains as to whether concerns over DBPs (and the cancer and reproductive risk tradeoffs) discouraged officials from expanding chlorination efforts.

United States Environmental Protection Agency experts working in Peru did find a reluctance on the part of the Peruvian Minister of Health to push for new or increased chlorination, based on DBP concerns.[21] Similar concerns were noted by Peruvian researchers interviewing water treatment plant engineers in various Peruvian towns, for example, in Trujillo.[18] But the experiences in Trujillo and Iquitos make it clear that there were ample reasons to expect cholera, once introduced into the population, to spread rapidly through an inadequate water distribution system, regardless of attitudes toward chlorination risks on the part of public health officials.

Additionally, the reluctance to expand chlorination efforts seems to be more complex than simply concerns about DBPs. Peruvian researchers have noted that the reluctance expressed by some authorities appears to result from the inherent constraints of a poor country, including practical and economic difficulties, inadequate supplies of chlorine, logistical difficulties in purchasing enough chlorine, and improper machinery.[18] DBP concerns may have simply provided a convenient rationale for the complex set of factors that limited expanded chlorination.

6. CONCLUSIONS

Multiple interconnected factors, including limitations in basic public health infrastructure, contributed to the 1991 cholera epidemic in Peru. Even full chlorination of drinking water in Peru probably would not have prevented the epidemic, though more aggressive preepidemic disinfection efforts would probably have played an important role in reducing the magnitude of the epidemic. While concerns were raised by some Peruvian health and water treatment authorities about DBPs, the evidence indicates that there was never a decision to "stop" chlorinating the drinking water (chlorination occurred in many locations) and that any reluctance to expand chlorination was more likely due to economic and infrastructure limitations. The assertion that officials actually stopped chlorinating as a direct consequence of DBP concerns seems to be more myth than reality.

The Peruvian cholera epidemic case demonstrates the importance in good public health practice of understanding the root causes of disease. In this case there were multiple root causes of the cholera epidemic, including the lack of proper disposal of human waste; limited and poorly maintained water treatment and distribution systems; poor hygiene practices resulting in contamination of food and water; dumping of cholera-contaminated sewage in coastal waters; and, quite possibly, global climate changes. Many of these factors had existed for years. Perhaps the most important root cause of the epidemic, however, is poverty and the social and economic inequities and marginalization in many parts of the world that inhibit access to clean drinking water. In the 1980s in Peru there was massive migration to Lima and coastal cities caused by rural poverty and civil strife. Simultaneously, the 1980s saw some of the lowest investments in water treatment and sanitation in Peru's history. Many of these cities lacked basic water infrastructure to deal with the influx of population and as a result less than 40% of Peru's urban population, much of which lived in shanty towns, lacked potable water sources in their houses.(6) While the important health benefits of water treatment and sanitation had been known to public health authorities for quite some time,(27) a range of factors limited their application in this case.

Unfortunately, too many public health professionals, decisionmakers, and others have considered the 1991 cholera epidemic as a case of the pitfalls of the precautionary principle. This is clearly not the case. The manner in which the Peruvian epidemic has come to be understood by some in industry, the media, and public health officials and policymakers alike, clearly demonstrates the need to have a holistic understanding of complex sets of events rather than simple sound bites that present only part of the story.

It is important that public health officials recognize the misuse of cases such as this to discredit precautionary and preventive policies and that they be more skeptical before accepting such cases as true. Repetition and ultimate acceptance of such false examples (in this case based on a single-page news article in the journal *Nature* with no citations(12) but refuted in a 1992 editorial in the *Lancet*(29)) as reality can distract attention from preventing real, yet uncertain risks as well as understanding the root causes of incidents such as the cholera epidemic.

Such cases also divert attention from real limitations in scientists' and policymakers' abilities to characterize and prevent complex and uncertain risks. They distract from the numerous examples of failures to apply precaution and the well-documented implications for health, the environment, and the economy.(29) Finally, they inhibit discourse on the means to improve science and public health decision-making processes to prevent disease and avoid real risk tradeoffs. Goldstein notes how well-intended, precautionary public health interventions can result in serious adverse consequences.(30) Seeking to avoid creating new problems while solving existing ones needs to be an important aspect in any application of precautionary interventions.

The precautionary principle can serve as a useful tool to stimulate discussions on ways to improve risk science and decisionmaking under uncertainty in order to more proactively reduce risks while stimulating innovation in safer processes and products. While every decision tool, precaution included, will likely result in some failures, we believe that the cholera example has failed to adequately demonstrate the pitfalls and failures of the precautionary principle.

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