
Volume 1, Issue 1, January 2012
ISSN 2211-4645
ELSEVIER
ENVIRONMENTAL
DEVELOPMENT
The Transdisciplinary
Journal of
SCOPE

Environmental Development 1 (2012) 3–9

Contents lists available at SciVerse ScienceDirect

Environmental Development

journal homepage: www.elsevier.com/locate/envdev

John Snow, the Broad Street pump and the precautionary principle

Bernard D. Goldstein

University of Pittsburgh, Pittsburgh, PA, United States

ARTICLE INFO

Article history:
Accepted 30 August 2011

Keywords:
John Snow
Precautionary principle
Environmental science
Epidemiology
Toxicology

ABSTRACT

In 1854 John Snow was responsible for a major advance in environmental health science when he demonstrated that cholera epidemics were waterborne rather than airborne. By mapping the disease outbreak he identified a specific London water source, the Broad Street pump, as its proximate cause. Removal of the pump handle was temporally related to the end of the epidemic. For his very careful mapping of an epidemic resulting in a new understanding of the cause of disease John Snow is considered to be the father of the science of epidemiology. More recently, many who advocate the precautionary principle have adopted this historic event as paradigmatic of action taken under precaution. They point out that Snow's efforts occurred before the identification of the cholera microbe or an understanding of the germ theory of disease. Snow's example seems to demonstrate that it is important to act on the possible association of a cause with an effect without a theoretical underpinning for the association and in preference to obtaining the scientific information needed to appropriately inform the decision. In contrast, I argue that Snow, an accomplished inhalation toxicologist, used his basic science knowledge to discard the erroneous associations that had previously led to the belief that cholera was an airborne disease. Snow's action is in many ways the antithesis of a precautionary approach in that his rigorous science overturned mistaken and harmful conclusions about the cause of cholera, which had been based on well documented but non-causal associations.

E-mail address: bdgold@pitt.edu

2211-4645/$ - see front matter © 2012 Published by Elsevier B.V.
doi:10.1016/j.envdev.2011.12.002

1. Introduction

My goal is to briefly consider the role of science in making decisions about potential environmental threats by using the lens provided by the removal of the Broad Street pump handle in response to a cholera epidemic in London in 1854. This was based on the scientific conclusions, and the personal urging, of John Snow who believed that cholera was spread through drinking water rather than through air (Snow, 1855). Snow accurately traced the source of the epidemic to the Broad Street pump by mapping the disease outbreak (Johnson, 2006; Koch, 2005; Leaman, 1984; Paneth, 2004; Smith, 2002; Vinten-Johansen, 2003). For this achievement he is considered to be the father of the science of epidemiology (Winkelstein, 1995; Paneth, 2004). I will relate this analysis to the contemporary issue of acting on environmental issues in the face of scientific uncertainty, often discussed under the heading of the precautionary principle. My thesis is that the story of the Broad Street pump handle, which is often cited as an iconic example of a precautionary action based upon an observed association, is more appropriately characterized as demonstrating the importance of a strong basic scientific understanding in protecting human health and the environment.

John Snow is also considered an ancestor figure in anesthesiology for his work in developing this field, and for his being chosen to give Queen Victoria anesthesia during childbirth, which did much to advance the acceptance of anesthesia by the public (Vinten-Johansen, 2003). His work on cholera and his work on anesthesia are usually considered two separate achievements by this remarkable man, but in fact they are related.

In this paper I argue that Snow's scientific reasoning that led to removal of the Broad Street pump handle was based upon his same sound understanding of toxicological mechanisms that led him to be a pioneer in anesthesia. I base this in part on the work of Paneth (2004), who pointed out that it was Snow's research on the properties of gases that led to his intense skepticism about the miasma theory of disease.

2. The cause of cholera

Cholera is a disease characterized by rapid onset of explosive diarrhea, massive dehydration, and death. It is caused by the bacillus *Vibrio cholerae* and spread through fecal contamination of drinking water or food. In the 19th Century epidemics began in Asia and then spread to Europe and the Americas. Medical opinion was that it was spread through the air, in keeping with the miasma theory of disease. Overcrowding and poor sanitation were thought to lead to air contamination and the rapid spread of the disease, particularly in low-lying foggy areas near rivers and other bodies of water. Diseases such as malaria (literally, bad air) were associated with mists over swampy areas. Drainage of low lying areas lowered the incidence of malaria and other diseases, an observation considered to be further proof that disease was spread through the air.

Cholera first appeared in England in 1831 and was characterized by a high incidence and fatality rate in local areas—one village of 550 inhabitants recorded 320 cases and 55 fatalities (Vinten-Johansen, 2003). During the initial epidemic and a subsequent reoccurrence in 1848 there were intense scientific debates about its cause (Smith, 2002). The two major theories of disease at the time were those of the contagionists and those of the anti-contagionists. Cholera fit neither theory very well. Its rapid onset fit best with anti-contagionism; and its dependence on human contact fit best with contagionism (Vinten-Johansen, 2003). But among the medical and scientific experts involved in these often acrimonious debates there was general agreement that disease was spread by air.

The belief in the airborne spread of cholera not only fit the prevailing theories of disease at the time, but also was consistent with the general spread of the disease from East to West along routes of sea trade. There also was significant evidence supporting this theory, evidence that today would arguably lead to invoking the precautionary principle. An example is the work of William Farr who is regarded as one of the founders of modern health statistics. Farr, and member of the Royal Society, worked at the General Register Office of England and Wales where he developed advanced methods to record and analyze causes of disease (Langmuir, 1976). Among his arguments in favor of the miasma theory of airborne spread was a careful analysis of cholera mortality in relation to the altitude above the Thames River with its mist and effluvia. Farr elegantly demonstrated that the relative mortality was far lower in those who lived on higher ground (the mortality per 10,000 population was 174 in those living 0–10 ft above the Thames; 53 in those living 30–40 ft above the Thames; and 24 in those living 80–90 ft above the Thames; Vinten-Johansen, 2003). Based on these data he concluded that Snow's theory about the waterborne cause of cholera was erroneous when it was first proposed in 1854. However, to Farr's credit, he provided Snow with access to cases on which to gather his statistics, and in later years came around to agree with Snow.

Parenthetically, cholera is still a feared disease. While the case fatality rate has declined due to rehydration therapy, it is still estimated to cause 3–5 million cases and 100–120,000 fatalities yearly (WHO, 2011). Major epidemics are currently occurring in Haiti and in Somalia

3. The precautionary principle and John Snow

The precautionary principle is notoriously difficult to define. The role of science in the precautionary principle and in precautionary actions has been the subject of much discussion, including differences in the requirement for scientific evidence depending upon the definition—differences which are often grouped under "strong" and "weak" definitions (Ashford, 2004; Barrett and Raffensperger, 2002; Cranor, 2003, 2004; Comba and Passetto, 2006; Foster et al., 2000; Goldstein 1999; Goldstein and Carruth, 2003; Grandjean, 2004; Kriebel et al., 2001; O'Brien, 2003; Stirling and Gee, 2002; Tickner, 2003; Van den Belt, 2003). The point I am making in this article is about what I believe is the erroneous attribution of John Snow's work to the "strong" definitions in which relatively minimal evidence suggesting the possibility of harm allows the invocation of action. As the precautionary principle becomes increasingly incorporated in international treaties and in national and local governance, the potential impact of the strength of the interpretation on the development of environmental health science becomes greater.

Two definitions of the Precautionary Principle illustrate the difference. One of the earliest formal definitions is that given in Rio de Janeiro by the United Nations Conference on Environment and Development, 1992:

> Nations shall use the precautionary approach to protect the environment. Where there are threats of serious or irreversible damage, scientific uncertainty shall not be used to postpone cost-effective measures to prevent environmental degradation.

A more stringent definition is given in the Wingspread declaration (Raffensperger and Tickner, 1999):

> When an activity raises threat of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.

The differences between the two include the thrust of the statement: Wingspread asserting that "measures should be taken" while Rio is phrased more passively "lack of certainty should not postpone measures". There are specifications for "serious or irreversible damage" and "cost-effective measures" in Rio; and neither requirement is mentioned in Wingspread. Finally, Wingspread extends the precautionary principle from the environment to public health (Goldstein and Carruth, 2004).

The literature on the precautionary principle reveals numerous instances in which John Snow and the Broad Street pump have been cited as an early or initial example of a successful precautionary action (Kurland, 2002; Harremoes et al., 2001; Gee and Stirling, 2003; Snedeker, 2003; Jarosinska and Gee, 2007; Pass and Pass, 2009; Barrieu and Sinclair-Desgagne, 2010). It is often noted that Koch's postulates were not formulated until three decades later, and the bacterial cause of cholera had not yet been identified — points that have been central to those who view John Snow as providing a rationale for the stronger versions of the precautionary principle. However, in my view, it is appropriate to consider John Snow's work on cholera as the basis for the precautionary principle only if the definition of the precautionary principle is restricted to "weak" decisions based on scientific understanding, not simply on observation of an association. There are always new scientific facts to be unveiled concerning any causal linkage, as the tobacco industry has continued to remind us (Samet, 2008).

Of course, as is well recognized in public health, the degree of scientific predictability is only one of the factors in acting on a threat: the consequences of not making the decision and the economic and social costs of the action also must be taken into account (Farrow, 2004). This is recognized in precautionary approaches through the principle of proportionality.

4. John Snow and his science

Snow was born in 1813. Although his father is described as a poor laborer, Snow was educated in a private school and at age 14 became an apprentice to a physician in Newcastle-on-Tyne (Leaman, 1984).

Snow's studies on respiration began before he graduated medical school, including a paper published in the London Medical Gazette in 1841: "On asphyxia, and on the resuscitation of still-born children" which included his experimental work in guinea pigs (Snow, 1841). He continued studies of respiration and of asphyxia in laboratory animals, which he very rapidly extended to the new field of anesthesiology. His study of anesthetics demonstrated that he was particularly adept at understanding the gas laws that govern the relation between liquid volume and gas concentration, including the role of temperature on vapor pressure, as well as the practical importance of gas delivery systems to the accurate delivery of dose. This skill set was central to Snow's contribution to the safe delivery of anesthetic gases and to his being considered as one of the original leaders in the science of anesthesiology (Vinten-Johansen, 2003: Zuck, 2004). The University of California at Los Angeles, in its website devoted to John Snow, lists 107 of his publications of which, by my count, 56 are related to anesthesia and 27 to cholera (UCLA, 2011).

Not surprisingly, anesthesia was highly controversial in its first years. Unwanted side effects, including death, were not uncommon, and many were opposed to its use. Public acceptance is usually dated to Queen Victoria's decision to have anesthesia during the birth of her eighth child—and it was John Snow who was selected to be the anesthesiologist.

Snow's work in anesthesiology began soon after its first use in 1846. In many ways his scientific approaches were both innovative in his time and highly relevant today. The development and use of biological markers is currently central to environmental science. Most impressive to a modern toxicologist who has struggled to develop useful biomarkers linking exposure and effect is Snow's work on chloroform in which he related the external chloroform exposure level to the blood chloroform level and to the observed extent of central nervous system anesthetic effects. I am unaware of any prior example linking the external level of a chemical with biological markers of both exposure and of effect.

Snow's switch from ether to chloroform, and his exploration of other potential anesthetic agents, was marked by close adherence to what would be considered modern pharmacokinetic and toxicokinetic methodology. He systematically considered absorption, distribution, metabolism and excretion as central to understanding the activity of an external agent. This is summarized in Snow's final publication that appeared in 1858, shortly after his death: "*On Chloroform and Other Anesthetics, and Their Action and Administration*." His research interests, shared by others, included developing predictive information for new anesthetics based upon what would now be called chemical structure–activity relationships. In his development of new chemical anesthetics he was guided by the avoidance of unwanted side effects in a way that, although rudimentary, is not dissimilar to the goals of the green chemistry of today (Anastas and Eghbali, 2010).

Snow's work on anesthesia, which continued throughout his life, preceded his attention to the cholera epidemics that recurrently affected London. Snow published his belief that cholera was a waterborne disease during the 1848 epidemic when he was fully immersed in his study of anesthetic agents. In his 1849 pamphlet on cholera explaining his reasoning about the spread of cholera in drinking water, he apologizes for his being unable to provide:

> "… a more extensive examination, and only to have published his opinions in case he could bring forward such a mass of evidence in their support as would have commanded ready and almost universal assent; but being preoccupied with another subject, he could only leave the inquiry, to bring it forward in its present state…" (Winkelstein, 1995).

The other subject was anesthesia, and the ‘‘present state’’ in 1849 was one in which he had formulated a reasonable hypothesis based upon his scientific understanding of inhalation physiology and toxicology, but had not fully tested it. It was the 1854 cholera epidemic, which permitted him to test his hypothesis through mapping the disease incidence in relation to sources of drinking water in London.

His first administration of anesthetic to Queen Victoria occurred in 1853, the year before the Broad Street pump event. This was also the year that Snow was chosen to give the annual oration of the Medical Society of London, a high honor from his colleagues for this then 39 year old physician. He began his oration with chemistry and physics before discussing his theory about cholera. Winkelstein (1995), an epidemiologist, suggests that this introduction reflects Snow’s interest in the medicinal use of gases and also hypothesizes that epidemiologists are not familiar with Snow’s document because they are put off by these ‘‘obtuse pages’’. However, it seems at least plausible that Snow’s choice to discuss chemistry and physics before presentation of his arguments related to the waterborne origin of cholera is indicative of his thinking as a basic scientist. It seems more than reasonable that his 1853 presentation reflected his consideration of the puzzle presented by the devastating recurring epidemics of cholera would have been informed by his scientific interest in understanding the inhalation of gases. This understanding of the respiratory tract led him to discount the accepted belief that cholera was an airborne disease. It also was the scientific base on which he conducted his studies when cholera returned in 1854.

Although he did not dwell on the issue in any of his writings, Snow did believe that the cholera agent multiplied in the intestines (Snow, 1855). He used an analogy to helminthic gastrointestinal parasites for which there was then evidence that unseen ova were responsible for spread (i.e., a possible biological cause)—but was careful not to commit to whether the cholera agent was alive or not. In addition to his own work, Snow’s reasoning is also provided in a short description in Lancet of his presentation to the Medical Society of London in 1854 (Headland, 1854). This included the absence of blood changes in cholera patients, which he points out would have been expected if a toxin was being transported from the lung to the gastrointestinal tract.

5. Discussion

The issue I have addressed is whether John Snow’s insight on cholera was based solely on noting a geographic association; i.e., whether removing the Broad Street pump handle should be seen as a rationale for a precautionary approach based on generating a hypothesis, or should be viewed as an example of the importance of deeper scientific understanding for effective preventive action to protect the environment.

My assertion that Snow would be uncomfortable with being cited as an iconic figure for the stronger definitions of the precautionary principle is supported by his testimony against the sanitary revolution. Lilienfeld (2000) has called Snow the ‘‘first hired gun’’ for his parliamentary testimony in 1855 supporting industry against the Nuisances Removal and Diseases Prevention Amendment Bill. Snow’s arguments in his testimony before the Parliamentary committee considering sanitary measures were based on toxicological reasoning. Snow was clearly aware of the dilution of a volatile agent as it moves from a source and hence the lower dose to community residents. Snow testified that if concentrated these gases would cause injury; but as the workers were not seen to be affected, he did not expect community members to be harmed, despite the unpleasant odor. In his testimony he carefully distinguishes between cholera, which he states ‘‘I consider that the cause of cholera is always cholera: that each case always depends upon a previous one’’ and the effects of gas inhalation which depend upon the presence of the gas (Lilienfeld, 2000). He does not appear to have considered issues related to differences in human susceptibility, nor the greater duration of exposure that occurs in community members as compared to workers. However, it is likely that in mid-19th century London this distinction was blurred by a much longer work week and by worker housing in proximity to their place of employment.

In his response to criticism of his views on industrial air pollution, Snow took pains to point out that his position on the toxicity of gases had nothing to do with his opposition to the miasma theory of cholera. Rather, he had held these views long before he had become concerned about cholera (Vinten-Johansen, 2003).

In science, and particularly environmental sciences, we often distinguish between studies that generate hypotheses and those that test hypotheses. Rather than simply developing an idea based upon using mapping to note an association, John Snow was testing an informed hypothesis that cholera was a waterborne disease. This hypothesis, developed before the 1854 epidemic, was based on what was for then an advanced scientific understanding of the mechanisms of disease causation. His response to the 1854 outbreak was that of a scientist taking advantage of an opportunity to test his hypothesis, including gathering more data and developing an intervention. Snow tested his existing hypothesis not only through careful mapping of the disease cluster, but also by tracking the outcome of the intervention after convincing public health authorities of the need to intervene. While there is some indication that the epidemic was ending anyway, it is reasonable to assume that had cholera cases continued to develop after removal of the pump handle, John Snow would be known today solely for his contribution to anesthesiology.

Snow's recognition as being a founding figure in both anesthesiology and epidemiology should not be considered as two unrelated scientific achievements, but rather as the result of a single inquiring scientist bringing his understanding of mechanisms of action of external agents to both. Snow's existing hypothesis was based upon his rigorous scientific investigation of the dynamics of the respiratory tract, including the uptake of foreign agents through inhalation that allowed him to discard erroneous hypotheses concerning an airborne cause of cholera. Rather than an example of a precautionary approach John Snow's work on cholera is an example of successful transdisciplinary research.

Another misconception about the Broad Street pump is highly pertinent to today's environmental science. Snow is often described as having himself physically removed the handle of the Broad Street pump. Rather, what he did is to convince the local health authority to do so. Without the existence of such an authority, and its willingness to act on the advice of scientific experts, John Snow would not be known as the father of epidemiology, or mistakenly credited as providing the first example of a strong precautionary action.

The removal of the pump handle also can be questioned as a precautionary action as little cost was involved. It was an inconvenience to those who needed to walk a few streets further to get water (Harremoes et al., 2001; Barrieu and Sinclair-Desgagne, 2010). Invoking the precautionary principle requires both scientific uncertainty and significant economic or social cost as there would be no need to invoke the precautionary principle if the science was certain or the costs were trivial (Goldstein and Carruth, 2003).

The Broad Street pump handle has become an icon of the field of epidemiology. Its representation of science in the service of public and environmental health should not be trivialized by considering John Snow to have arrived at his conclusions solely by recognizing an association. Rather, its lesson for today is the need to invest in a strong scientific base for making informed decisions to prevent environmental health problems and to appropriately utilize precautionary approaches.

References

Anastas, P, Eghbali, N, 2010. Green chemistry: principles and practices. Chemical Society Reviews 39, 301–312.

Ashford, N., 2004. Implementing the precautionary principle: Incorporating science, technology, fairness, and accountability in environmental, health, and safety decisions. International Journal of Occupational Medicine and Environmental Health 17 (1), 59–67.

Barrett, K., Raffensperger, C., 2002. From principle to action: applying the precautionary principle to agricultural biotechnology. International Journal of Biotechnology 4 (1), 4–17.

Barrieu, P, Sinclair-Desgagne, B., 2010. On precautionary policies. Management Science 52, 1145.

Comba, P., Passetto, R., 2006. Precautionary principle: scientific evidence and public health action. European Journal of Oncology 11 (3), 153–156.

Cranor, C.F., 2004. Toward understanding aspects of the precautionary priniciple. Journal of Medicine and Philosophy 29 (3), 259–279.

Cranor, C.F., 2003. What could precautionary science be? research for early warnings and a better future. In: Tickner, J.A. (Ed.), Precaution: Environmental Science and Preventive Public Policy. Island Press, Washington, pp. 305–320.

Farrow, S., 2004. Using risk assessment, benefit–cost analysis, and real options to implement a precautionary principle. Risk Analysis 24 (3), 727–735.

Foster, K.R., Vecchia, P, Repacholi, M., 2000. Science and the precautionary principle. Science 288, 979–981.
Gee, D., Stirling, A., 2003. Late lessons from early warnings: improving science and governance under uncertainty and ignorance. In: Tickner, J. (Ed.), Precaution, Environmental Science and Preventive Public Policy. Island Press, Washington, DC.
Goldstein, B.D., 1999. The precautionary principle and scientific research are not antithetical. Environmental Health Perspectives 107, A594–A595.
Goldstein, B.D., Carruth, R.S., 2003. Implications of the precautionary principle to environmental regulation in the United States: Examples from the control of hazardous air pollutants in the 1990 Clean Air Act Amendments. Law & Contemporary Problems 66, 247–261.
Goldstein, B.D., Carruth, R.S., 2004. The precautionary principle and/or risk assessment in World Trade Organization decisions: a possible role for risk perception. Risk Analysis 24, 491–499.
Grandjean, P., 2004. Implications of the precautionary principle for primary prevention and research. Annual Review of Public Health 25, 199–223.
Harremoes, P., Gee, D., MacGarvin, M., Stirling, A., Keys, J., Wynne, B., et al., 2001. Late Lessons from early Warnings: The Precautionary Principle 1896-2000 No. 22). Copenhagen 2001: OPCE (Office for Official Publications of the European Communities).
Headland, 1854. Medical Society of London, Saturday, October 14, 1854. Lancet, October 24, 1854.
Jarosinska, D., Gee, D., 2007. Children's environmental health and the precautionary principle. International Journal of Hygiene and Environmental Health 210, 541–546.
Johnson, S., 2006. The ghost Map: The Story of London's most Terrifying Epidemic—and How it Changed Science, Cities, and the Modern World. Riverhead Books, New York 2006. 299 p.: ill., maps; 24 cm.
Koch, T., 2005. Cartographies of Disease: Maps, Mapping, and Medicine, 1st ed. ESRI Press.
Kriebel, D., Tickner, J., Epstein, P., Lemons, J., Levins, R., Loechler, E.L., et al., 2001. The precautionary principle in environmental science. Environmental Health Perspectives 109, 871–876.
Kurland, J., 2002. The heart of the precautionary principle in democracy. Public Health Reports 117 (6), 498–500.
Leaman, A., 1984. John Snow MD—his early days. Anaesthesia 39 (8), 803–805.
Langmuir, AD, 1976. William Farr: founder of modern concepts of surveillance. Internal Journal of Epidemiology 5, 13–18.
Lilienfeld, D.E., 2000. John Snow: the first hired gun? American Journal of Epidemiology 152 (1), 4–9.
O'Brien, M., 2003. Science in the service of the good: the precautionary principle and positive goals. In: Tickner, J.A. (Ed.), Precaution: Environmental Science and Preventive Public Policy. Island Press, Washington, pp. 279–296.
Paneth, N., 2004. Assessing the contributions of John Snow to epidemiology: 150 years after removal of the broad street pump handle. Epidemiology 15 (5), 514–516.
Pass, M.A., Pass, R., 2009. The environment and maternal and child health. In: Ehiri, J (Ed.), Maternal and Child Health: Global Challenges, Programs and Policies. Springer.
Raffensperger, C., Tickner, J., 1999. Appendix A: Lessons from Wingspread, Protecting Public Health and the Environment: Implementing the Precautionary Principle. Island Press Washington, DC, pp. 349–355.
Samet, J.M., 2008. Secondhand smoke: facts and lies. Salud Publica de Mexico 50 (5), 428–434.
Smith, G.D., 2002. Commentary: behind the broad street pump: aetiology, epidemiology and prevention of cholera in mid-19th century britain. International Journal of Epidemiology. 31 (5), 920–932.
Snedeker, S.M., 2003. What is the precautionary principle? How is it taking shape nationally and globally? Cornell University Program on Breast Cancer and Environmental Risk Factors 8, 4–11.
Snow, J, 1841. London Med. Gazette, vol. 29:222–227. Available in Frerichs, R.R. Principal Writings of John Snow, UCLA School of Public Health Department of Epidemiology. 〈http://www.ph.ucla.edu/epi/snow/principalwritings.html#2〉.
Snow, J, 1855. On the Mode of Communication of Cholera, London. John Churchill.
Snow, J., 1858. On Chloroform and Other Anaesthetics, and Their Action and Administration.
Stirling, A., Gee, D., 2002. Science, precaution, and practice. Public Health Reports 117, 534–545.
Tickner, J.A., 2003. Precautionary assessment: a framework for integrating science, uncertainty, and preventive public policy. In: Tickner, J.A. (Ed.), Precaution: Environmental Science and Preventive Public Policy. Island Press, Washington, pp. 265–278.
University of California at Los Angeles Department of Epidemiology School of Public Health Principal Writings of John Snow 〈http://www.ph.ucla.edu/epi/snow/principalwritings.html〉 accessed July 12, 2011.
Van den Belt, H., 2003. Debating the precautionary principle: "guilty until proven innocent or "innocent until proven guilty"? Plant Physiology 132, 1122–1126.
Vinten-Johansen, P., 2003. Cholera, Chloroform, and the Science of Medicine: A Life of John Snow. Oxford University Press, Inc., New York.
United Nations Conference on Environment and Development, 1992. Final Declaration, Principle 15. Rio de Janeiro.
Winkelstein Jr., W., 1995. A new perspective on John Snow's communicable disease theory. American Journal of Epidemiology 142 (Suppl. 9), S3–S9.
World Health Organization, 2011. Cholera, Fact Sheet 107, August 2011. 〈http://www.who.int/mediacentre/factsheets/fs107/en/〉.
Zuck, D, 2004. John Snow and anaesthesia. Journal of the Royal Society of Medicine 97, 153–154.