6 Beryllium's 'public relations problem'

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Scores of workers employed in nuclear weapons production have been diagnosed with chronic beryllium disease (CBD), a progressive and irreversible inflammatory lung disease. This chapter presents a history of knowledge and public policy about preventing beryllium-related disease, focusing primarily on the United States beryllium industry's role in shaping US regulatory policy.

Over several decades increasingly compelling evidence accumulated that CBD was associated with beryllium exposure at levels below the existing regulatory standard. The beryllium industry had a strong financial incentive to challenge the data and decided to be proactive in shaping interpretation of scientific literature on beryllium's health effects. It hired public relations and 'product defence' consulting firms to refute evidence that the standard was inadequate. When the scientific evidence became so great that it was no longer credible to deny that workers developed CBD at permitted exposure levels, the beryllium industry responded with a new rationale to delay promulgation of a new, more protective exposure limit.

This case study underscores the importance of considering the hazards from toxic materials throughout the entire product life cycle. While primary producers of beryllium products may be able to control exposures in their own facilities, it is unlikely that many secondary users and recyclers have the expertise, resources and knowledge necessary to prevent beryllium disease in exposed workers and residents in nearby communities.

The primary lessons of this chapter are widely applicable to many environmental health controversies. In particular, it illustrates the practice of 'manufacturing uncertainty' — a strategy used by some polluters and manufacturers of hazardous products to prevent or delay regulation or victim compensation.

This chapter is followed by an analysis of the rationale for corporate behaviour in the regulation of beryllium. It is argued that the availability of occasional and limited opportunities for companies to change course without suffering onerous consequences would encourage them to rethink their position and create an obligation on shareholders to take the responsible course. Although this may be perceived as letting them 'get away with it', the end result may be better public policy and corporate responsibility.

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6.1 Introduction

In a dramatic announcement on a national television news magazine in April 2000, Bill Richardson, the United States Secretary of Energy, acknowledged that his department had collaborated with the beryllium industry to defeat a 1975 attempt by the Occupational Safety and Health Administration (OSHA) to reduce workers' exposure to beryllium. The collaboration had been documented in a powerful newspaper exposé (Roe, 1999). 'Priority one was production of our nuclear weapons', Richardson stated, '[the] last priority was the safety and health of the workers that build these weapons' (ABC, 2000).

The Secretary of Energy's declaration was remarkable; rarely do the most senior officials in government admit deception that resulted in death and disability of its own citizens. Yet, for those in the public health community, Richardson's candid announcement was long overdue. Scores of workers employed in nuclear weapons production have been diagnosed with Chronic Beryllium Disease (CBD), a progressive and irreversible inflammatory lung disease. In the decades leading up to the announcement, increasingly compelling evidence accumulated that CBD was associated with exposure at levels below the standard in place at the time. In response to this evidence, the beryllium industry waged a concerted campaign to delay a safer standard. The industry hired public relations and 'product defence' consulting firms to refute evidence that the old standard was inadequate. Eventually, when the scientific evidence became so great that it was no longer credible to deny that workers developed CBD at levels permitted by an out-dated standard, the beryllium industry responded with a new rationale to delay promulgation of a new, more protective exposure limit.

In the television interview, Secretary Richardson described how the Department of Energy (DOE) had changed course, and was now lowering the level that triggered protection for beryllium-exposed workers in the US nuclear weapons complex from 2.0 $\mu g/m^3$ to 0.2 $\mu g/m^3$ (micrograms of beryllium per cubic meter of air). The Department's new Chronic Beryllium Disease Prevention Program was designed to provide further protection for workers from a substance so hazardous that no safe level of exposure has ever been established.

The DOE standard covers only workers employed in the nuclear weapons complex. Although OSHA has acknowledged the inadequacy of its present workplace beryllium exposure limit, it has not updated its standard, which covers workers in the private sector. Researchers at the National Institute for Occupational Safety and Health (NIOSH) have estimated that there are between 28 000 and 107 000 private-sector workers potentially exposed to beryllium in the US; only 1 500 of these are employed in primary producers of beryllium products (Henneberger et al., 2004).

This case study presents a history of the knowledge and public policy about preventing beryllium-related disease, focusing primarily on the US beryllium industry's role in shaping US regulatory policy. A similar investigation has been performed in the United Kingdom (Watterson, 2005). Although the present study primarily discusses events in the United States, it is worth noting that Brush Wellman, the leading US manufacturer of beryllium products, has operated factories in Europe and that Brush Wellman's actions influenced beryllium safety and health policy throughout the world.

The present study is based on a review of documents and on the personal knowledge of one of the authors (David Michaels), who, as Assistant Secretary of Energy for Environment, Safety and Health, directed the DOE efforts to issue a stronger beryllium standard and develop a programme to provide compensation payments to workers with CBD. Some of the documents cited were obtained from government files and others were provided by attorneys who obtained them via litigation.

6.2 Early warnings and the first beryllium workplace exposure standard

The first significant industrial use of beryllium occurred in the 1930s, in production of fluorescent lamp tubes. Soon after the metal was first introduced, dozens of workers employed at fluorescent lamp factories in Massachusetts developed a form of chemical pneumonitis now known as Acute Beryllium Disease (ABD) (Hardy, 1950). It quickly became apparent that workers could not safely work with beryllium without respiratory protection.

Beryllium's importance grew dramatically with the Manhattan Project, the secret initiative to construct atomic weapons, and the subsequent expansion of the nuclear weapons industry, fuelled by the Cold War. This lightweight metal is a vital component in nuclear weapons. Beryllium slows down the neutrons released when an uranium atom is split in an atomic chain reaction; this facilitates the splitting of more atoms, thereby increasing a weapon's power, or 'yield'. In the early years of US nuclear weapons production many cases of beryllium disease occurred among workers employed at privately operated beryllium production plants and among residents living near these facilities.

To its credit, the DOE's predecessor, the Atomic Energy Commission, acted quickly. Coming soon after the success of the Manhattan Project, the AEC had a group of very capable scientists who had virtually invented the field of radiation protection (Hacker, 1987). The AEC focused its attention on beryllium, funding numerous studies at laboratories and universities throughout the country. Most importantly, AEC environmental health specialists developed a beryllium exposure limit.

In many ways, the AEC had no choice but to tackle the problem directly. Since the weapons complex was now the nation's primary consumer of beryllium products, the AEC tacitly assumed responsibility for researching the health perils that the valuable metal posed. In a 1947 report, *Public Relations Problems in Connection with Occupational Diseases in the Beryllium Industry*, the AEC openly acknowledged problems of both 'obvious moral responsibility' and public relations, the latter exacerbated by the fact that, unlike remote research and bomb-making facilities, some beryllium-processing factories were located in more populous areas. The 1947 report states bluntly,

> 'There is no doubt at all that the amount of publicity and public indignation about beryllium poisoning could reach proportions met with in the cases of silicosis or radium poisoning.' It also notes that the industry was already reporting problems recruiting workers 'because of local prejudice … engendered by actual and rumored experience with beryllium poisoning' (Tumbelson, 1947).

The origin of the AEC beryllium exposure limit is discussed in the autobiography of Merril Eisenbud, an AEC industrial hygienist who went on to be the Environmental Protection Administrator of New York City. Eisenbud describes how he and Willard Machle, a physician who was a consultant to the firm building the Brookhaven Laboratory in Long Island, New York, decided on the number while in the back seat of a taxi on their way to a meeting at the laboratory in 1948. In his autobiography, Dr Eisenbud reports that he and Dr Machle selected 2 μg/m^3 for workplace exposures and 0.01 μg/m^3 for community exposures 'in the absence of an epidemiological basis for establishing a standard' (Eisenbud, 1991). Instead, the scientists used what Herbert Stokinger of the US Public Health Service later described as a 'crude analogy' to protect health (Stokinger, 1966).

The AEC 'tentatively' adopted these exposure limits in 1949 and then reviewed them annually for seven years before permanently accepting them (Stokinger, 1966). The agency applied this exposure limit in its own facilities and incorporated adherence to the exposure limit into its contracts with manufacturers that supplied it beryllium products. OSHA later adopted the 2 μg/m^3 limit when it first issued workplace exposure standards in 1971. While the story of Eisenbud's 'taxicab standard' has been often retold, a recent reviewer of the historical data has suggested that the workplace exposure limit was actually selected on the basis of feasibility not health protection (Egilman et al., 2003).

The 2 μg/m^3 exposure limit was a great step forward. It was very stringent for its time, and its acceptance was probably aided by two factors. The first was that it addressed a severe problem; the human cost of acute beryllium disease was so great that the accompanying 'public relations problems' threatened the AEC's mission. Second, nuclear weapons production was well funded — essentially a 'cost-plus' operation in which the participating companies were assured a healthy profit. For the most part, the weapons plants were run by private employers, with the US government reimbursing their costs, plus an additional percentage awarded as profit. The largest US manufacturer of beryllium products was Brush Wellman, now known as Materion; Brush (as it was often called) was both a vendor to the US government and a contractor, operating a beryllium products production facility for the AEC in Ohio from 1950 to 1956.

The 2 μg/m^3 exposure limit was an immediate success; ABD virtually disappeared and there appeared to be a reduction in new cases of CBD as well. But it was not long before questions arose about the level of beryllium exposure necessary to cause CBD.

6.3 The science and its use

6.3.1 Evidence of CBD at exposures below the 2 μg/m^3 standard

With funding from the AEC, Dr Harriet Hardy established the Beryllium Case Registry (BCR) at the Massachusetts General Hospital in 1952. ABD and

CBD case reports were sent to the BCR, to track the disease and to aggregate a sufficient number of cases to conduct epidemiologic analyses (Hardy, 1955; Hall, et al., 1959; Hardy, 1962). As of 1972, the BCR had recorded at least 20 CBD cases among workers who started employment after 1949, the year the AEC exposure limit was adopted (NIOSH, 1972). By 1975, that number had risen to at least 36 (OSHA, 1975), suggesting the disease might be occurring in workers whose exposure was below the 2 μg/m^3 exposure limit. Moreover, CBD had been diagnosed in persons with no workplace exposure to the metal, including individuals who simply laundered the clothes of workers, drove a milk delivery truck with a route near a beryllium plant, or tended cemetery graves near a beryllium factory (NIOSH, 1972).

Although the acute illness was typically seen among workers exposed to very high levels of soluble forms of beryllium, the distribution of the chronic form of beryllium disease did not follow the usual exposure-response model seen for most toxic substances. Instead, CBD was found among workers and community residents without substantial exposure histories. As early as 1951, Sterner and Eisenbud reported that exposure levels were not correlated with CBD severity, and hypothesised an immunological susceptibility (Sterner and Eisenbud, 1951).

Scores of workers exposed to beryllium from manufacturing nuclear weapons developed Cronic Beryllium Disease.

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In 1966, *Beryllium: Its Industrial Hygiene Aspects*, was published under the direction of the American Industrial Hygiene Association for the AEC. Dr Stokinger, the editor of the text, asserted that:

> 'Numerous cases of the chronic disease have occurred from exposures to seemingly **trivial** concentrations of a beryllium compound that at higher levels produced no effect; no dose-response relationship appears to hold' (Stokinger, 1966) (emphasis added).

It was becoming increasingly clear that a simple, linear dose-response relationship (risk increasing in direct proportion to dose) did not apply to this metal, and that it might not be possible to identify a threshold below which no CBD cases would occur.

In these early years, the community cases were evidently viewed as anomalous, or the result of episodes of high exposure. CBD incidence among workers did appear to drop dramatically with the reduced exposure associated with the standard, leading to speculation at the time that the 2 μg/m^3 exposure limit might be overly conservative (Breslin and Harris, 1959; Stokinger, 1966). There thus appeared to be a conundrum: how could there be community cases and occasional case reports of workers with very low exposures, while the standard appeared to be effective in systematic studies of beryllium production workers? With hindsight, we can speculate that the explanation is that CBD is an immune-mediated disease with considerable inter-individual variability in susceptibility, and a dose-response relationship which is probably driven by 'peak' exposures — possibly of very short duration — which standard methods of exposure assessment do not detect.

Throughout the 1970s and 1980s, CBD case reports involving workers whose exposures were below 2 μg/m^3 continued to emerge. In 1974, for example, representatives of NGK, a Japanese beryllium producer that also operated a manufacturing facility in the US, travelled to the US to meet with local beryllium industry executives. The Japanese delegation brought a report of five CBD cases that had occurred among workers exposed below the 2 μg/m^3 standard (Kohara, 1974; Shima, 1974). Similar cases occurred at US plants, including four cases among workers at a single scrap metal reclamation facility who were consistently exposed to beryllium below 2 μg/m^3 (Cullen et al., 1987).

Today, it is understood that CBD is initiated by an immune system response to beryllium exposure; the associated adverse health effects begin well before the disease has pulmonary manifestations that allow diagnosis with a chest x-ray or pulmonary function test (Newman et al., 1996). The first published reports of CBD diagnosed using blood lymphocyte proliferation tests (BeLPT) appeared in 1983 (MMWR, 1983). By the end of the decade the diagnostic techniques had progressed significantly, allowing clinicians to more easily identify individuals with beryllium sensitisation (BeS), an immunologic condition that is a precursor to CBD (Kreiss et al., 1989; Mroz et al., 1991).

Using the BeLPT as a screening tool, researchers have found CBD prevalence rates ranging from 0.1 to 4.4 % among beryllium-exposed workers in the nuclear weapons, ceramics, primary beryllium manufacturing, metal machining, and copper-beryllium alloy industries, with Be(S) prevalence in these groups from 0.9 to 9.9 %. In most of these surveys, workers identified through the BeLPT as beryllium sensitised were given clinical evaluations to determine whether they had CBD. Depending upon the workplace, the CBD rate among workers with BeS ranged from 9 to 100 % (Kreiss et al., 1993a; Kreiss et al., 1993b; Kriess et al., 1996; Stange et al., 1996; Kreiss et al., 1997; Deubner et al., 2001; Henneberger et al., 2001; Newman et al., 2001; Stange et al., 2001; Sackett et al., 2004; Welch et al., 2004; Rosenman et al., 2005; Schuler et al., 2005; Schuler et al., 2008).

These studies diagnosed CBD or BeS among workers, including clerical workers and security guards, who had only experienced bystander exposure to beryllium. Clinical follow-up studies have found that individuals with BeS progress to CBD at a rate of 6 % to 8 % per year, but it is not known if all individuals with BeS will eventually progress to CBD (Newman et al., 2005).

6.3.2 *Evidence of beryllium's capacity to cause cancer*

In addition to its non-malignant effects on the lungs, beryllium has been shown to be a lung carcinogen. By the 1970s, significant toxicological evidence had accumulated on beryllium's carcinogenic effects, leading an NIOSH official to assert in 1977 that 'probably no compounds known to man give so consistent a carcinogenic response in so many animal species as do the compounds of beryllium' (NIOSH, 1977). This indictment of the potential risk of beryllium exposure compelled OSHA to propose a new occupational exposure limit for beryllium of 1 μg/m^3, measured as an eight-hour time-weighted average. NIOSH then recommended lowering the permissible exposure limit further, to 0.5 μg/m^3 (NIOSH, 1977).

Brush Wellman assembled a team of toxicologists, statisticians and physicians to challenge the new regulatory initiative (Michaels, 2008). The stakes were high for Brush: 'If beryllium is determined to be a carcinogen and so labelled and so regulated it would only be a matter of time until its usage would shrink to a point where it would no longer be a viable industry' (Brush Wellman, 1977). Ultimately, intense lobbying by the industry and the US Departments of Defense and Energy and the election of President Ronald Reagan prevented OSHA from finalising a new workplace exposure limit (Roe, 1999). Nonetheless, NIOSH continued to conduct epidemiological studies of cancer risk among beryllium-exposed workers (Steenland and Ward, 1991; Ward et al., 1992). The results of these studies, along with the extensive animal evidence, led the International Agency for Research on Cancer to list beryllium and beryllium compounds as Group 1 agents (i.e. carcinogenic to humans) in 1994 (IARC, 1994) and to reaffirm the designation in 2009 (Straif et al., 2009). Similarly, the US National Toxicology Program designated beryllium in 2002 as a 'known human carcinogen' (NTP, 2002).

6.3.3 *The beryllium industry's public relations efforts*

The increasing evidence of adverse health effects associated with beryllium exposure continued to create a problem for the industry. If government agencies formally designated beryllium as a substance for which there is no safe exposure level or as a carcinogen, the economic consequences for the industry could be significant. The industry's customers would be more likely to look for substitutes for the light-weight metal (Brush Wellman, 1977; Hanes, 1992b).

Beryllium producers decided to be proactive in shaping the interpretation of scientific literature on beryllium's health effects. Aspects of the programme were detailed in a 1987 internal Brush Wellman memo, with the subject line 'Proposed program for filling need for new and accurate beryllium health and safety literature'. The memo by Martin B. Powers, a retired Brush Wellman executive who was a consultant to the company, and Dr Otto P. Preuss, Corporate Medical Director, warned:

> '… the literature on Be published in the last twenty years has been very damaging. The

> literature is constantly being cited, either to our doctors at medical meetings in rebuttal of the Brush experience, or by potential customers as the cause of their unwillingness to use our products. Federal Government regulatory agencies, such as OSHA and EPA [the US Environmental Protection Agency], publish much of this material and then in the absence of good data, cite these erroneous documents to support regulatory activities.'

> 'What is needed to combat this situation is a complete, accurate and well written textbook on Be health and safety. It will have to be financed by Brush (or Brush and NGK?) and the bulk of the work done by Marty Powers and Otto Preuss. To be fully acceptable and credible, however, it will have to be published under the auspices of some not-for-profit organisation such as a university or medical group. … In addition to the book, we should have a number of medical papers published in prestigious medical books' (Powers and Preuss, 1987).

Beryllium: Biomedical and Environmental Aspects was published in 1991; two of its editors were Martin Powers and Otto Preuss, along with a respected academic physician (Rossman et al., 1991).

In the face of increasing evidence about the toxic effects of their products, the beryllium industry also turned for assistance to the public relations (PR) firm Hill & Knowlton (Hill & Knowlton, 1986). This firm has gained much notoriety for its now well-known efforts in manufacturing and promoting scientific uncertainty for the tobacco industry (Brandt, 2007; Glantz et al., 1996). In the proposal it sent to Brush describing how it could help, Hill & Knowlton echoed the AEC 'public relations problem' memo of 1947:

> 'Beryllium undoubtedly continues to have a public relations problem. We still see it cited in the media, as well as in our conversations with people who should know better, as a gravely toxic metal that is problematic for workers … We would like to work with Brush Wellman to help change these common erroneous attitudes. We envision a public relations program designed to educate various audiences … to dispel myths and misinformation about the metal' (Marder, 1989a).

Hill & Knowlton proposed to prepare 'an authoritative white paper on beryllium … [which] would serve as the most definitive document available on beryllium.' The PR firm also suggested projects to engage outside scientists in independent reviews of Brush Wellman materials, 'to nurture relations with the Environmental Protection Agency' and 'to challenge all unfair or erroneous treatment in the media to set the record straight' (Marder, 1989a).

Appended to the letter was a document in which Hill & Knowlton boasted of their experience assisting other corporations who faced regulatory difficulties stemming from their production of hazardous products, including asbestos, vinyl chloride, fluorocarbons and dioxin. There was no mention, however, of the firm's work for the cigarette manufacturers. Matthew Swetonic, the staff member proposed to direct the PR effort, had been a key player in Hill & Knowlton's efforts on behalf of a cigarette manufacturer to convince the public that non-smoker exposure to environmental tobacco smoke was harmless (Swetonic, 1987) and to 'create a favorable public climate' to assist in defeating lawsuits filed by smokers with lung cancer (RJR Nabisco, no date). In addition, Swetonic had previously performed public relations work for Johns-Manville, the asbestos producer, and had been the first full-time executive secretary of the Asbestos Information Association (Asbestos Textile Institute, 1973).

Once hired, Hill & Knowlton sought to reassure Brush's customers of the safety of beryllium. The firm drafted a series of letters for Brush to send to their beryllium ceramic customers, downplaying beryllium's hazardous properties (Marder, 1989b; Davis, 1989a; Davis, 1989b).

6.3.4 Manufacturing uncertainty about beryllium and disease

By the late 1980s, the continued incidence of new CBD cases raised concerns among health and safety professionals who previously believed the 2 $\mu g/m^3$ 'taxicab standard' was adequate to protect workers from CBD. Dr Eisenbud, who had become a consultant to Brush Wellman, notified the company in 1989 that 'he did not feel that he could defend the 2 microgram standard any longer' (Rozek, 1989).

The rising number of CBD cases also contributed to an increase in litigation. Brush management recognised that a change in the OSHA standard could be used in legal suits brought by sick workers. 'Maintaining the existing [OSHA] standard is fundamental to successfully defending against any product liability litigation', a Brush official asserted in 1989 (Rozek, 1989). This effort was an integral part of Brush's Health, Safety and Environment Strategic Plan in 1991:

> 'Employ legal means to defeat unreasonably restrictive occupational and emission standards and to challenge rulemaking and other regulatory activities that seek to impose unreasonable or unwarranted changes. Resist an attempt to make the existing occupational exposure standard of 2 micrograms/cubic meter, as measured and calculated by Brush, more restrictive. The standard is safe, it is one of the most stringent standards, and it is fundamental to our product liability defense' (Rozek, 1991).

In contrast, the evidence of the standard's inadequacy was clear to the DOE. In 1991, the nuclear weapons agency began the process of lowering the exposure limit to reduce workers' risk of developing CBD. The change was opposed by the beryllium industry, whose position is summarised in this excerpt from a 1992 Brush Wellman letter:

> 'We regret that DOE apparently still intends to abandon the existing standard of over 40 years standing with no evidence, either that the existing standard is unsafe or that the new proposed standard affords any greater degree or [sic] safety. The NIOSH recommendation of 1977, which fortunately no one ever adopted, of 0.5 micrograms, introduced an element of confusion that can only be compounded by DOE's proposed introduction of a third number. A proliferation of numbers as 'standards' can only weaken the acceptance, and therefore, the efficacy of the individual protection afforded. Confusion is never in the best interests of the worker' (Hanes, 1992a).

Progress on a more protective rule was also impeded by opposition from within the DOE. The offices responsible for manufacturing nuclear weapons argued that money spent protecting workers would mean less money for producing arms. The debate continued for several years, leaving the proposed rule in limbo.

Despite the institutional obstacles, US government safety officials continued to advocate a new, more protective standard. The DOE health and safety office sponsored a series of public forums to gather information on beryllium's health effects. At one session, Brush Wellman's Director of Environmental Health and Safety asserted (according to minutes of the meeting): 'Brush Wellman is unaware of any scientific evidence that the standard is not protective. However, we do recognize that there have been sporadic reports of disease at less than 2 $\mu g/m^3$. Brush Wellman has studied each of these reports and found them to be scientifically unsound' (DOE, 1997).

This was the industry's primary argument; subsequent studies have demonstrated that the underlying logic to the argument was flawed. At the time, however, it was not difficult to go back into the work history of anyone with CBD and speculate that, at some point, the airborne beryllium level may have exceeded the standard. Even if no evidence for overexposure was found, it was assumed that exposure over the standard had occurred because the worker had developed CBD. Brush did this, and then reasoned that the 2 $\mu g/m^3$ must be fully protective since everyone who had CBD must have at some point been exposed to levels above the standard.

Although flawed, this tautological construct served as the basis for Brush's defence of the 2 $\mu g/m^3$ exposure limit. Talking points prepared for Brush executives advised:

> 'you may be asked in some fashion whether or not the 2 $\mu g/m^3$ standard is still considered by the company to be reliable. Your answer should be as follows:
>
> 1. Experience over several decades has, in our view, demonstrated that levels of airborne beryllium within the OSHA threshold limit value afford a safe workplace.
>
> 2. In most cases involving our employees, we can point to circumstances of exposure (usually accidental), higher than the standard allows. In some cases, we have been unable (for lack of clear history) to identify such circumstances. However, in these cases we also cannot say that there was *not* excessive exposure' (emphasis in original) (Pallum, 1991).

This position, however, could not be maintained indefinitely. As the DOE provided medical screening to more workers, the number of CBD and BeS cases continued to grow, reaching several hundred by the middle of the decade (DOE, 1998). Moreover, the growing literature reporting cases of CBD associated with low levels of exposure undermined the claim that the old standard was safe (Wambach and Tuggle, 2000). Scores of beryllium-exposed workers who had developed CBD filed civil suits against Brush, alleging that the firm failed to disclose information about the material's toxicity. Continued denial of the relationship between low-level exposure and CBD was unlikely to be a successful strategy to oppose either the claims raised by sick workers or the attempts by the DOE and OSHA to strengthen their beryllium exposure standards. Instead, Brush Wellman asserted that not enough was known to prevent CBD from occurring. If true, the industry might avoid liability in CBD litigation.

In 1998, Brush Wellman and NIOSH embarked on a collaborative research initiative, conducting medical surveillance of beryllium-exposed workers and examining the beryllium-CBD relationship. The research partnership has been productive, delivering findings that have substantially contributed to the literature on beryllium disease (NIOSH, 2002).

In December 1998, the DOE officially proposed a rule to protect workers from CBD, including an action level of 0.5 μg/m^3, or 25 % of the OSHA standard, and asked for public comment on the proposal (DOE, 1998). Brush Wellman no longer asserted that the old standard was effective in preventing CBD but instead took the position that not enough was known to prevent CBD from occurring. During a public hearing in February 1999, a Brush representative offered this new rationale for the DOE to delay issuing a new standard. He testified that 'important research is underway which may provide a scientific basis for a revision to the occupational standard for beryllium,' pointing to studies on particle size, particle number and particle surface area (Kolanz, 1999).

For assistance in promoting this new strategy, Brush turned to Exponent, Inc., a US firm that provides scientific and technical support to polluters and manufacturers of dangerous products (Exponent, Inc., 2006). Exponent, Inc. is a leading practitioner of 'product defence', a specialisation that aims to help corporations reduce their regulatory burden and defeat liability claims that arise in the civil justice system (Michaels, 2008). With Exponent's assistance, in September 1999 Brush Wellman convened a conference, co-sponsored by the American Conference of Governmental Industrial Hygienists, to bring 'leading scientists together to present and discuss the current information and new research on the hazards posed by beryllium' (Paustenbach et al., 2001).

At the time of the conference, the DOE was a few months away from issuing its final ruling, and OSHA had recently signalled its intention to revise its outdated 2 μg/m^3 standard (OSHA, 1998). The paper summarising the proceedings, entitled 'Identifying an Appropriate Occupational Exposure Limit (OEL) for Beryllium: Data Gaps and Current Research Initiatives' voiced the same position that DOE officials had heard earlier in the year. Specifically, that more research was needed on the effects on CBD risk of particle size, exposure to beryllium compounds and skin exposure. Although it is not uncommon for a scientific paper to call for additional research, this paper went further, advocating postponement of any changes in the workplace beryllium exposure standard: 'At this time,' the paper concludes, 'it is difficult to identify a single new TLV (threshold limit value) for all forms of beryllium that will protect nearly all workers. It is likely that within three or four years, a series of TLVs might need to be considered… In short, the beryllium OEL could easily be among the most complex yet established' (Paustenbach et al., 2001).

In December 1999, the DOE completed its work, mandating that protection from beryllium exposure in DOE facilities be triggered at 0.2 μg/m^3 rather than the 0.5 μg/m^3 level the agency had proposed some months earlier (DOE, 1999). In its ruling, DOE relied on a common industrial hygiene measure of exposure: full-shift concentration by weight of airborne beryllium.

The government's responsibility is to protect public health using the best available evidence. More research was, and is, needed, but since the relationship of CBD to beryllium particle size, number of particles and surface area was, and remains, poorly understood, the officials responsible for protecting the health of beryllium-exposed workers determined that new policy should not be delayed until this research was completed.

6.3.5 New evidence but no new OSHA standard

Once the DOE prepared to issue its new standard, OSHA, the lead US agency for worker safety and health, recognised an opportunity to update its own beryllium standard. In written comments to the DOE, OSHA's Assistant Secretary acknowledged the inadequacy of the current OSHA standard, writing:

> 'we now believe that our 2 μg/m^3 PEL does not adequately protect beryllium-exposed

> workers from developing chronic beryllium disease, and there are adequate exposure and health effects data to support [the DOE's] rulemaking.'

The letter continues by citing existing data:

> 'Cases of chronic beryllium disease have occurred in machinists where 90 % of the personal exposure samples found levels of beryllium to be below the detection limit of 0.01 µg/m^3 … Viewed from OSHA's regulatory perspective, these DOE study results document risk of sensitization to beryllium of 35–40 per 1 000 workers and risk of chronic beryllium disease to machinists of 94 per 1 000' (Jeffress, 1998).

Despite a commitment to issue a new standard by September 2001 (OSHA, 2000), OSHA did not propose a rule to protect beryllium-exposed workers. When President George W. Bush's Administration took office in 2001, OSHA formally dropped its commitment to strengthen the beryllium standard, asserting it needed more information before deciding how to proceed (OSHA, 2002).

Scientific knowledge on the risks associated with low-level beryllium exposure continues to accumulate, silencing those who had previously defended the adequacy of the current standard. In the few years since DOE issued its standard, US researchers, including several affiliated with Brush Wellman, have published several epidemiologic studies that provide additional evidence that OSHA's standard does not fully prevent CBD (Henneberger et al., 2001; Kelleher, et al., 2001; Schuler et al., 2005; Stange et al., 2001; Rosenman et al., 2005; Madl et al., 2007). Finally, in 2006, a literature review and editorial supported by Brush Wellman acknowledged that the current OSHA standard 'provides insufficient protection for beryllium-exposed workers' (Borak, 2006).

Beryllium exposure continues to be a public health concern at 'downstream' facilities, which use beryllium products but are not involved in primary production, in recycling facilities, and in communities adjacent to beryllium-processing facilities. In 1999, the diagnosis of a sentinel CBD case in a metals recycling plant in Quebec, Canada resulted in the identification of 31 additional cases at three metals plants (Robin, 2005). It also prompted a survey that identified 2 789 workplaces where beryllium was used in that province, including 63 golf club manufacturers and 15 bicycle manufacturers (Tremblay, 2005). There have also been eight new cases of community-acquired CBD recognised between 1999 and 2002 in the US (Maier et al., 2008)

Given the wealth of new research, is it now possible to identify a safe level of beryllium exposure? Unfortunately, it is not. There are many complex questions to answer, and there are relatively few workplaces in which these questions can be easily studied. A committee of the US National Research Council recently concluded that 'it is not possible to estimate a chronic inhalation-exposure level that is likely to prevent BeS and CBD' (National Research Council, 2008). This scepticism is shared throughout the scientific community; in the opinion of three NIOSH scientists, the evidence gathered to date suggests that 'attempts to define a safe air concentration of beryllium for all workers are not likely to be successful' (Kreiss et al., 2007).

This uncertainty does not, however, justify deferring implementation of programmes to reduce exposure. There is ample evidence that interventions designed to reduce beryllium exposure to the lowest achievable levels have successfully decreased BeS and CBD incidence (National Research Council, 2008). Furthermore, in 2009 the American Conference of Governmental Industrial Hygienists issued a Threshold Limit Value recommendation of 0.05 µg/m^3, which is well below both the current OSHA and DOE standards (ACGIH, 2009).

Since at present there is no compelling evidence for a safe level of beryllium exposure, it would be prudent public health policy for manufacturers to substitute a less toxic material for beryllium whenever possible. However, in those products and processes in which there is no adequate substitute for beryllium, such as the production of nuclear weapons, exposure should be reduced to the lowest level technically feasible.

6.4 Lessons for policymakers

The primary lessons of this case study are widely applicable across many environmental health controversies.

The first is that **the absence of evidence is not evidence of absence**. In the decades following the reduction in beryllium exposures in the early 1950s, relatively few new CBD cases were diagnosed. This is likely attributable both to improved working conditions and the limitations of the diagnostic methods available at the time. With the development of the BeLPT, many new cases were diagnosed, no doubt including cases that would not have been previously recognised as CBD.

There were indications before the advent of the BeLPT, however, that the 2.0 µg/m³ standard was not fully protective. As CBD and BeS were diagnosed in an increasing number of workers with low exposures, this conclusion became more difficult to avoid.

As this evidence accumulated, the beryllium industry had a strong financial incentive to challenge the data, and to oppose regulatory action that would result in a lower exposure limit. It appears this incentive shaped the interpretation given to scientific evidence by scientists employed by the beryllium industry.

This, then, is the second lesson of the case study: **interpretation of scientific data by those with financial incentives for misinterpretation must be discounted**. Scientists employed by the beryllium industry defended the 'taxicab standard' long after it was correctly recognised as inadequate by independent scientists. In particular, work by scientists employed by firms specialising in product defence and litigation support must be seen for what it is: advocacy, rather than science.

This study illustrates the practice of '**manufacturing uncertainty**' — the strategy used by some polluters and manufacturers of hazardous products to prevent or delay regulation or victim compensation (Michaels and Monforton, 2005; Michaels, 2008). The public health paradigm requires that the best available evidence be used to protect the public. By the early 1990s, the accumulated evidence was sufficient for public health officials to justify a more protective workplace beryllium exposure limit. In response, the industry manufactured and magnified uncertainty, producing a series of arguments about why the old standard should not be changed. Extensive research has subsequently confirmed the inadequacy of the OSHA standard; a more protective standard will help prevent CBD and save lives.

Finally, the findings of this case study underscore the importance of **considering the hazards associated with a toxic material throughout the entire life cycle of the product**. While primary producers of beryllium products may be able to control exposures in their own facilities, it is unlikely that many secondary users and recyclers have the expertise, resources and knowledge to prevent beryllium disease in exposed workers and residents in nearby communities. As a result, it would be prudent public health policy to end industrial use of beryllium, except in circumstances where substitution is impossible.

Table 6.1 Early warnings and actions

1930s	First industrial uses of beryllium and first reported cases of beryllium disease
1949	AEC adopted the 2.0 µg/m³ exposure limit for weapons workers
1952	Establishment of Beryllium Case Registry
1971	OSHA adopted the 2.0 µg/m³ exposure limit
1975	OSHA proposed a 1.0 µg/m³ exposure limit but this was never approved
1980s	BeLPT used to diagnose cases of CBD
1989	DOE proposed a 0.5 µg/m³ exposure limit for DOE weapons and clean-up workers
1999	DOE issued a 0.2 µg/m³ exposure limit for DOE weapons and clean-up workers
2009	ACGIH recommended a 0.05 µg/m³ exposure limit
2012	OSHA has yet to propose new workplace beryllium standard

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Corporate behaviour in the regulation of beryllium: could there have been a different outcome if the company had room to turn around?

Tee L. Guidotti ([3])

The response of commercial organisations to uncertainty with respect to environmental and occupational risks continues to challenge regulators and parties interested in a regulatory intervention in the face of corporate resistance.

Viewed from within the organisation, corporate objectives and protection align with other seemingly valid reasons to oppose change and create a stronger argument from within than may be perceived from the outside. One suspects that most corporate leaders involved in situations like this live in a world of cognitive dissonance and denial rather than cupidity. Few people, other than sociopaths, tolerate the belief that they cause harm and suffering. Rather, most people with strong personalities tend to deny their role in a bad situation and the consequences of their actions, and to believe the denial. Reinforced by group-think, rationalisation, corporate culture, and a technical staff able and willing to provide justification for the denial, such behaviour becomes normative. The challenge is not to condemn the behaviour — that is easy. It is to understand it in order to control it. (Prevention is probably not possible given human nature.)

Beryllium: a case study

Michaels and Monforton (2008 and present volume) have published a comprehensive history of the occupational exposure standard for beryllium in the US and its failure to adequately protect workers. Their work is a valuable contribution to our understanding of the beryllium issue, about which there have been a number of serious misconceptions (Guidotti, 2008).

The only significant manufacturer and supplier of beryllium metal in the US, Brush Wellman, used various arguments to rationalise opposition to the proposed beryllium standard, first asserting that 2 µg/m^3 was adequate, then playing on uncertainty, challenging the data on which the proposals were grounded, first for beryllium disease and later for carcinogenicity. In this they were initially abetted by the US Department of Energy (DOE), which initially resisted an evidence-based precautionary protective standard, presumably to protect the nuclear industry. There were many allegations of scientific malfeasance and inappropriate political influence. Notwithstanding the fact that both DOE and the American Conference of Governmental Industrial Hygienists, a major voluntary body recommending exposure guidelines, have proposed lower occupational exposure limits, the federal regulator, the Occupational Safety and Health Administration, has still not proposed a new 'permissible exposure limit' for beryllium after at least 35 years of deliberation.

Brush Wellman was, and still is, a highly profitable company that had, and still has, a near monopoly on the product. At the time it had little other business, although it is now more diversified. The company stands accused by Michaels and Monforton of cupidity and arrogance in resisting a protective federal standard in the face of steadily accumulating evidence for the toxicity and carcinogenicity of the metal. Doubtless, the company has a different narrative, but this panel is not about the company's culpability. Seen another way, the story of Brush Wellman, and other companies, is a case study in organisational behaviour and response. However, it may also be read slightly differently to be about pathway dependence and how the initial worldview of a highly organised institution may commit it to a line that ultimately proves disgraceful for itself and tragic for the victims of occupational hazard.

The doctrine of 'shareholder value' and resistance to changing course

Michaels and Monforton assume throughout that the reluctance of Brush to accept new findings regarding Be risk was motivated by the desire to maintain corporate revenues. To set the stage, it is important to realise that, in the US, there appears to be no recognised legal responsibility of corporations other than to shareholders and to obey the law. The concepts of corporate responsibility and of corporate beneficence have been litigated many times and decisions have consistently upheld the interests of shareholders above all other stakeholders (Pérez Carolli, 2007). The most famous example of this is a 1919 Michigan Supreme Court decision that blocked Ford Motor Company from reducing the price of Model T automobiles as a public benefit (and

([3]) This text is an adaptation of a critical review prepared for the European Environmental Agency, Copenhagen, as part of *Late lessons from early warnings*.

to create a larger consumer class) at the expense of paying dividends to shareholders. Some legal scholars have argued, persuasively, that this ruling has been misunderstood and its significance has been exaggerated (Stout, 2008). However, there have been many other decisions that have had the collective impact of emphasising that although a corporation may act in a beneficent manner, it is not entitled to do so at the expense of shareholder interests, at least not without their permission.

From the legal point of view, and at least from a lay reading of the legal situation, which is at least what corporate officers would have understood in the 1950s and 1960s, corporations appear to be obliged to optimise value, profits, and shareholder interest, not community or social benefits except insofar as they advance the interests of the corporation and therefore the interests of the shareholders who own it. This reality can be lamented and argued, but it is deeply grounded in American jurisprudence and business culture.

The point to be made before further discussion is not that this concept is, or can be, abusive and antisocial — that it can be is obvious. It is that it was believed and that, notwithstanding waves of management interest in 'corporate responsibility' (most notably in the 1960s), this belief has been assumed in corporate culture and was part of a management philosophy of maximising 'shareholder value' for the last thirty years. Under US law, a corporation cannot be faulted for maximising profits, as long as they are within the law, just as an individual cannot be faulted for trying to minimise the taxes he or she pays, as long as the taxpayer is within the law. Whether Brush Wellman violated the law is outside the scope of this panel and is not directly addressed by Michaels and Monforton (2008).

Likewise, there is also the influence in business circles of the parallel and highly influential argument of Milton Friedman and the Chicago School of economists that the purpose of business is to increase wealth and that social benefit is a question of how that wealth is invested, a decision that the owners of the wealth should make, not the corporation (Friedman, 1970). One answer to Friedman would be that corporations are given a franchise to perform socially useful functions, providing goods and services in exchange for making profit, but this is not the forum to argue this point.

One obvious legal solution is for the interest of stakeholders to be revisited. If the corporation faces catastrophic sanctions if it admits it was wrong, then the interest of the shareholders in a corporation should be for it to capitulate. However, in the real world, fines are too low, sanctions are too weak, and legal actions too likely to settle for the anticipated consequences to force changes in corporate behaviour. The executives of a bad corporation are usually better off seeing the issue through to the end and then, if the consequences are dire, changing management, taking golden parachutes, and leaving the task of refurbishing the image of the company to the next executive team.

Another legal solution should be possible, however. If a corporation has the option of ending a course of action that would lead to consequences so serious that shareholders' interests would be compromised, they would then have a fiduciary and legal responsibility to their shareholders to retreat from an untenable position and accept the need to change course. Opportunities coming at key times in the narrative to change direction without onerous consequences could have made it possible for corporate leaders to drop their resistance to the proposed standard without admitting they were wrong. Creating such opportunities might make it possible for the leaders of such companies to change course on a pragmatic basis on the grounds that they are minimising loss to shareholders and reducing potential punitive damages that the company would have to pay.

Whether this policy would motivate corporate leaders on a destructive track to change course on their own initiative is uncertain, although it is likely that it would if the consequences are high. These are not stupid people, after all. What is certain is that legislation, regulatory policy, or a judicial opinion to this effect would create grounds for shareholders to take legal action against the officers of a corporation and put enormous pressure on them to change their position when it became untenable. Another advantage of such a policy is that it is consistent with conservative business values of responsibility to shareholders and maintaining shareholder value, and therefore hard to argue against.

National security and rationalisation

People tend to believe what is aligned with their own interest and do not recognise these beliefs as rationalisation. It is quite likely that corporate leaders of the day saw reasons other than corporate protection that aligned with their financial interests of profit maximisation. The sequence of events takes on new significance when seen from the perspective of the times.

Initially, the trade-off as seen from the ramparts of the military-industrial complex involved a risk/risk calculation in which the perceived security consequences would have been catastrophic and the potential for harm to workers seemed remote and uncertain. Issues of workers' rights to know, the sustainability of the industry without occupational health controls, and the uncertainty of risk from Be were undoubtedly secondary to security issues **as they were understood at the time**. In hindsight, this was highly unfortunate but at the time it was not unreasonable, given that the world was in a bipolar 'Cold War' between two nuclear powers, the Soviet Union and the US, together with its nuclear-armed allies France and the United Kingdom. Later, the rationale for opposing revision of the standard seems to have been based on a calculus of risk/benefit, in which the perceived risks of inadequate military defence with nuclear weapons was replaced by the perceived benefit to society of Be alloys.

In the context of an industry central to national security, it is not clear that the issue could have played out in any other way, unless there was some means of making a gradual transition to a more protective standard or resolving the uncertainties over the standard test for Be sensitivity (which in combination with a positive chest film or CT scan or biopsy results makes the diagnosis of beryllium disease) at an earlier stage. The 2 $\mu g/m^3$ standard is widely recognised as not adequately protective and was shown to be so at the time. However, once it was established, it took on a life of its own and became 'sticky' — that is, difficult to dislodge — until the evidence became overwhelming. This may have been, in part, because the leap to 0.5 $\mu g/m^3$ was or appeared to be too great technically and raised fears that the defence industry would be disrupted, leaving the country unacceptably vulnerable. However, reluctance to accept that a change was needed appears to have been driven mostly by uncertainties over the blood test (BeLPT), which was still in development and was perceived as unproven, a perception helped along by its alignment with financial interests.

Toward the end, it is clear that the emerging motivation for delay was perceived risk to the company. Here again there is another, unstated side to the story. It is clear that much of the opposition was self-serving but the company could legitimately have been seen at the time to be what is now called in 'homeland security' terminology a 'critical industry', providing an essential service or product. This dynamic would have, again, conflated the company's interests with the national interest (along the lines of 'what's good for us is good for the nation') and provided a rationale for maintaining the status quo on the grounds (specious but persuasive) that the company needed to stay in business and profitable to meet a national need.

Acceptable risk and accountability in risk assessment

It became apparent as the issue dragged on that no standard was fully protective, because of the stochastic (probabilistic, rather than deterministic) nature of the immune response. When this is true, as it is of many allergens, of fine particulate air pollution, and of lead exposure in children, the problem becomes one of determining 'acceptable risk' based on social criteria. Modern societies usually choose one in a million risk of a serious outcome or death as the acceptable risk, although in practice risks on the order of one in a thousand are the norm in occupational health. In this case, the company management was trying to make this determination alone, without collective input, because they (corporately) believed that they understood the problem best. However, they did not, and they were working in a social vacuum, focused on the company's priorities and beliefs. In a democracy, the question of 'who gets to decide' is answered formally by 'the representative of the people', that is, the government, and informally by who has possession of the data.

In the event, the initial standard of 2 $\mu g/m^3$ obviously worked well to reduce pressure to lower the standard. (It has since been reduced, first to 0.5 $\mu g/m^3$ in 1998 and then to 0.2 in 1999 but only as an internal standard within the Department of Energy, not through adoption by OSHA.) Although the story (told by Merril Eisenbud, who was involved in its formulation) that the initial 2 $\mu g/m^3$ was worked out in a taxicab on the way to the decisive meeting and was revised upward at the last minute, suggests an overly casual approach, in the absence of scientific evidence for a threshold or a 'no-observed adverse effects level' a reasonable consensus based on informed opinion is not a bad substitute for data. It certainly worked to eliminate acute Be disease, which was initially the concern. A standards-setting committee consisting of informed experts is not unlike a Delphi group, making sequential estimates based on feedback from the scientific literature and from their peers. It resembles (imperfectly) the estimation of an a priori probability in Bayesian statistics. Insisting on the inadequacy of a standard which was lacking more rigorous science, when evidence did not exist, is like applying the legal and political standards of today to ancient history. It is also difficult to find experts with practical experience outside the industry or with no interest in the outcome of deliberations, making conflict of interest a given and a matter of degree.

Michaels and Monforton make the blanket statement that 'The interpretation of scientific data by those with financial incentives must be discounted.' However, financial incentives attach to almost everyone who has a professional interest in a particular topic, including those who receive support, to be critical of a position and offer expensive tests. Thus, the essential problems, beyond disclosure, are not the financial incentives but the degree of influence exerted on the investigator, the completeness of reporting, and the validity of the information. The validity question can be further unpacked into issues of honesty and integrity, data quality, methodological issues, bias, handling of uncertainty, correct scientific interpretation of complicated evidence, and whether selection or misclassification bias is introduced due to business or other activities that attach to the position of the party involved. (For example, workers at a particular plant in the Be industry may be different from other workers or workers in other plants, such that a study sponsored by the company may have a bias. But the same may also be true of a study performed by an academic researcher.) Professional and personal incentives, which may be as powerful as financial incentives, attach to everyone involved because once a position is taken publicly it is human nature to be emotionally invested in defending it.

To their credit, Michaels and Monforton use the term 'discounted' rather than 'ignored', but in practice few who advocate tighter regulation may make the distinction. In fact, exclusion of corporately-sponsored research and the 'grey literature' risks losing an immense body of valuable information. Society is already denied significant benefit by obstacles to accessing proprietary information. Current practices within the insurance industry, for example, together with rules against collusion and price-fixing, militate against sharing information that would be highly useful in establishing the health risk of various groups, such as workers covered by workers' compensation (Guidotti, 2000).

Seen in this light, and assuming that accountability is not possible in the adversarial setting of business interests, the issue reduces to one of transparency. Can the data be audited and the analysis reconstructed? Who will ensure the integrity of the auditors? In this regard the experience of the Health Effects Institute (HEI) is pertinent. HEI routinely commissions a reanalysis of data from the most significant studies it supports on air pollution health effects, a process that to date has confirmed the original findings in every case but is considered essential to acceptance of the findings by industry (in this case, the automobile manufacturing industry). This model is not so easily to apply to corporately sponsored research, however, because there is no external mechanism for guaranteeing quality assurance and no contractual obligation to cooperate with an audit or means of ensuring transparency.

Another model that may be applicable is the current drive to require drug companies to register clinical trials, so that those that have negative results or that demonstrate harmful effects cannot be buried. Establishing a data repository is a logical step in this process but there would of course be legitimate issues of business knowledge, anti-trust prohibitions, and proprietary information to navigate. How such an arrangement could be enforced when applied to corporately-sponsored research is not clear but a voluntary approach led by responsible companies would place considerable pressure on those that did not participate.

However, these are technical solutions and partial at best. The deeper issue is one of organisational behaviour and commitment to a wrong decision in the face of diminishing room to manoeuvre.

One could have made the point in 1983 that acceptance of the BeLPT, the blood test for immune sensitivity, would have protected the company through demonstration of due diligence, but at the time a consensus on the validity of the assay had not emerged. (As Michaels and Monforton pointed out, it was impeded by the machinations of a cooperative academic. Even today, the BeLPT has to be positive in two tests before a diagnosis is considered to be confirmed.) Michaels and Monforton make a major case for the idea that 'the absence of evidence is not evidence of absence', however in the case of the BeLPT there was abundant evidence but the performance of the test was disputed. Until the test was validated, it was not unreasonable for non-scientists to be sceptical. The deeper question is who determines when a method is valid: scientists, regulators, or corporate interests? Likewise, who determines when data are sufficient and when evidence is actually absent?

Faced with uncertainty and bolstered by intimations that the test may not be definitive, it was actually a logical (and, from their point of view, probably responsible) decision for the company to delay and to require further information. As time went on, this position may have become untenable scientifically but the stakes were also rising. A late admission that the assay was valid would have been tantamount to admitting that the company had stalled and allowed further cases. In short, the company was pulled along in a situation in which, as uncertainty over the test diminished, the stakes increased, perhaps exponentially, making it increasingly difficult to accept or stop questioning the test and making it paradoxically more attractive to defend their earlier position. Small wonder that, in a classic demonstration of organisational behaviour, the company leadership did not want to admit, and as individuals probably truly did not believe, that they had erred.

Lessons learned

The Brush Wellman experience demonstrates that a significant internal disincentive of companies to accept new findings is fear of liability and reputational damage. Add to this the perceived fiduciary responsibility to shareholders, the shame of admitting that decisions may have harmed workers, and the (probably inflated) costs of installing more stringent controls and it is easy to see how denial and rationalisation would be the mode of behaviour. In the case of Be, these measures were relatively expensive: separation of sensitised workers through Be-free buffer zones and containment and reassignment of sensitised workers.

Seen in that light, and assuming that the Brush Wellman leadership was generally honest in their own terms (on the face of it, a problematical assumption), the company could be viewed as being pulled along by events into an increasingly untenable situation, until their position was completely indefensible. It would be going too far to characterise this as a 'tragedy' for them, in the dramatic sense of a fatal flaw that brings down the protagonist. However, it is apparent that one problem with the narrative is that there was never a moment at which Brush Wellman could change direction without paying what it considered to be an unacceptable penalty. Because of legacy liabilities, the deep investment the company had in believing otherwise, and the slow evolution of the science, the management of the company appears to have been slogging through a tunnel of diminishing dimensions, seeing no exit and no path except what lay ahead. At the beginning, the issue was cost (probably overestimated, as it usually is), loss of market share, and saving face. At the end, it may have been massive financial and legal liability.

Perhaps the key issue is at what point an organisation can change course, when it is allowed to do so, and how it can do so given its internal drivers and culture. The question may need to be recast as how information controlled by the company can be effectively accessed, with protection, so that the leadership has a viable escape route from an impossible situation.

The essential question for reconstructing the company's behavioural and motivational history is, therefore, was there ever a point along the way where it was 'safe' for Brush to change course? Was there an opening that allowed internal forces within the company that might have better understood the issue to break with the management line and to accept the health risks of Be at low levels without what they perceived to be unacceptable consequences (and psychic pain)?

This does happen. Liggett & Myers, the American tobacco company, made a dramatic break with the rest of the industry in 1996 and both settled tobacco-related cases and unilaterally declared that it accepted that smoking is addictive (Borio, 2003). It did so because it saw a window of opportunity to reduce its risk and because it recognised that the industry position had become untenable. (There is no reason to think that they did so because it was right or for the greater good. It was a business decision, pure and simple.)

If one expects corporations, and the attitudes of corporate leadership, to change in response to new information, rather than to fight new information because of fear, denial, or risk of loss, there must be exit or escape opportunities. This may mean unpalatable choices and bright lines where today the picture is murky, such as opportunities to forgive legacy liabilities, legal defences (such as a clear definition of when due diligence has been achieved), and a threshold for sufficient knowledge (a clear standard of when knowledge about risk is sufficient to act, not just first awareness that there may be a problem). Organisations cannot be expected to change their positions unless they are given a 'way out' that may involve forgiving past liability and reducing punitive damages. (This is largely what happened with the DOE contract worker's compensation programme.)

The threat of strong grounds for legal action or board action by dissident shareholders introduces a new counterweight to the equation and is a bigger stick than it might first appear. It is also not necessary to assume that shareholders would force management to choose the path of conciliation out of self-interest to protect their equity, or that a righteous shareholder rebellion would be provoked by outrage over corporate behaviour. After all, most shareholders are apathetic and unengaged in corporate governance. Rather, management would know that if they did not act appropriately, dissident shareholders or hostile suitors could use their failure to act opportunistically for their own purposes, using the argument that they were destroying shareholder value and should be replaced. Also, large shareholders (such as pension funds) are interested in stability and yield and are likely to avoid investing in companies that fail to take opportunities to reduce their risk exposure.

The lessons from the Be case are unpleasant but clear: if corporations are expected to reverse course, there must be room for them to turn around. Pressure builds resistance and ultimately denial and may be counterproductive at times. Perception and judgment align with interests, and people on different sides of an issue see the problem differently. Correcting the system to facilitate resolution may require trade-offs with unpleasant implications. The opening of opportunities for bad corporations to escape legal or financial consequences is not an attractive solution from the moral perspective but may lead to the greatest good for the greatest number.

Another lesson from the Be case is that once a standard is set, it becomes 'sticky'. It develops a constituency and an infrastructure to support it. Changing a standard has to overcome inertia and the accumulated weight of experience and acceptance. A policy of sequential standard-setting based on scientific evidence is inherently flawed. There will always be new scientific information. It is more reasonable to expect that standards will become more stringent and to accept a realistic policy of continuous improvement, anticipating that standards evolve rather than pretending that each standard is definitive. Standards can be as much impediments as instruments of worker protection. A policy of continuing improvement and progression over time in reducing exposures is the natural alternative approach, although perhaps unattainable in the current political context. The problems with such a policy lie in initiating it and sustaining it in an equitable manner.

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