Atmospheric Pollution and the British Copper Industry, 1690–1920

EDMUND NEWELL

"It is our unanimous opinion that . . . the said works will prove very much to the advantage and not in the least prejudicial or hurtful to our said borough and inhabitants thereof."1 This sanguine outlook was expressed by a local government officer, Alderman Powell, when copper smelting works were proposed in Swansea, south Wales, in 1720. At the time, Powell could not have realized the irony of his optimism. On the one hand, the emerging copper industry he was seeking to promote grew to such international importance and technological preeminence that the Swansea district became known as "Copperopolis" by the mid-19th century. On the other, copper works proved to be a serious source of industrial pollution, contributing significantly to turning the Swansea Valley into what has recently been described as "one of the most polluted landscapes in the world."2

Copper smelting and coal mining were the principal industries in the Swansea district in the 18th and 19th centuries, although the smelting of other nonferrous metals, including zinc, lead, and silver, contributed not only to the diversity of industrial activities but also

Dr. Newell was a doctoral student, Unilever Prize Research Fellow, and British Academy Postdoctoral Fellow at Nuffield College in the University of Oxford. His specialist area of research is the economic history of the copper mining and smelting industries. The author is grateful to the British Academy and to Nuffield College, whose support enabled this article to be written, and thanks Simon Watts, Peter Brimblecombe, Martin Daunton, Inge Harding-Barlow, Joshua Getzler, Christopher Hall, Susan Newell, the editors of this journal and anonymous referees, and participants at seminars at All Souls College, Oxford, Oxford Brookes University, and the University of East Anglia for their help and comments. He is also indebted to his vicar, the Reverend Ken Reeves, and parishioners in Deddington, Clifton, Hempton, and the Barfords, whose forbearance allowed him sufficient time away from his current duties as a clergyman to complete this project.


© 1997 by the Society for the History of Technology. All rights reserved.
0040-165X/97/3803-0005$02.00

655
Edmund Newell

to the fumes, dust, and debris that caused environmental degradation. It was not until the Lower Swansea Valley Project of the 1960s and 1970s, which reclaimed slag heaps and large tracts of derelict land, that Swansea was finally rid of an industrial heritage that was both an eyesore and an environmental hazard.3

Copper smelting was the main contributor to the devastation of the Lower Swansea Valley. Yet although the pollution problem associated with British copper works is well known, with the exception of two articles by Ronald Rees it has received little scholarly attention. Rees examined a small number of well-publicized court cases in south Wales in the period 1833 to 1895, conveying the impression that the problem manifested itself primarily as a legal issue among farmers, landowners, and smelting companies, in a particular area within a certain time span.4 In reality, the problem was more widespread and deep-rooted than Rees suggested, and concern was expressed by a broader group than he indicated, since pollution from copper works came under the close scrutiny of a parliamentary select committee, a royal commission, the Alkali Inspectorate, and other official bodies at the national and local levels. This article, therefore, takes a wider perspective by considering the social costs of atmospheric pollution from copper works and the ways in which these costs impinged upon smelting companies in the form of pressure from public lobbying, legal action, and local and national government legislation. It also considers the responses of smelting companies to these pressures, especially technological innovations designed to disperse atmospheric pollutants or to recover them as marketable by-products.

The story that will unfold is complicated, primarily because it involves a web of relationships among industrialists, local residents, farmers, landowners, scientists, doctors, lawyers, and politicians with vested interests in, or contributions to make to, the pollution issue. It also involves a large number of firms and numerous locations. Much of the activity, however, relates to the Swansea district in south Wales and to Liverpool and St. Helens in Lancashire, where most


British copper works were located (see fig. 1). At the industry's peak, in the mid- to late 19th century, eleven firms operated in south Wales and six in Lancashire. Of these two areas, the Swansea district was by far the more important, accounting for about 90 percent of British copper production during the period covered by this article. Furthermore, the story is intriguing, not least because atmospheric pol-
olution from copper works attracted the attention of eminent scientists, including Michael Faraday and Sir Humphry Davy, and major politicians, such as the sometime prime minister Lord Derby.

The conclusion reached is that while some firms paid considerable attention to the problem, most notably Vivian and Sons, the second largest firm in the industry for most of the 19th century, no satisfactory strategy or technological solution developed. It was the smelter John Henry Vivian (who was also member of Parliament for Swansea from 1832 to 1855) who first showed particular interest in the problem in 1812, and his concern was maintained by his son, the smelter Henry Hussey Vivian (who was member of Parliament for Glamorgan from 1857 to 1885 and became the first Lord Swansea in 1893). As will be shown, however, the limited success of the Vivi-ans and others, such as their rivals Pascoe Grenfell and Son, was a result of the difficulty of altering smelting methods, the costs involved, and a climate of opinion that was generally negative toward action that might stifle industrial activity. Instead, the problem was alleviated, and eventually eliminated, only by the decline and extinction of the British copper smelting industry. While this article is in general agreement with Rees, it will show that atmospheric pollution from copper works was a far more complex and less parochial issue than he suggested, and part of a much larger picture of a society struggling to deal effectively with the detrimental effects of industrialization.

The British Copper Industry

The period from the 1690s to the 1920s witnessed the rise and decline of the British copper smelting industry. In this time, the industry emerged from small beginnings to achieve international prominence, such that by the early part of the 19th century British copper production accounted for nearly half the estimated world total. Peak production was reached in the 1890s, although by then British output was relatively small in international terms.5

A major factor in the successful development of the British copper industry was the availability of cheap supplies of coal that were ideally suited to smelting. Copper was one of the first metals to be smelted commercially using coal, and the industry’s rapid growth stemmed from the use of coal-fired reverberatory furnaces. With a

fuel-to-ore ratio of more than two to one, it was rational to locate smelting works near coalfields rather than copper mines and to transport the ore to the coal so as to minimize freight costs. As a result, copper smelting in Britain became focused on two main locations during the 18th century: St. Helens and Liverpool near the Lancashire coalfield and, more important, the Swansea district on the southwestern edge of the south Wales coalfield (see fig. 1).

During the late 17th and 18th centuries, most of the copper ore utilized by British smelters was obtained from the British Isles, particularly from Cornwall, although mines in Anglesey enjoyed a brief success toward the end of this period. From the late 1820s, however, the opening up of overseas mining fields and the relaxation of tariffs led to the influx of ore imports, and Britain—especially Swansea—became the principal destination for copper ores mined in South and North America, Cuba, Australia, southern Africa, and elsewhere, as well as for British ores. Although attempts were made to establish smelting works overseas to tap these new supplies of ore, technical difficulties and the lack of suitable fuel prevented their initial success, to the benefit of British smelters.

During the second half of the 19th century, further developments in copper processing technology in the United States and elsewhere overcame most of the difficulties that had led to ores being exported to Britain and extended the range of ores that could be mined. For instance, new methods were introduced to process low-grade pyritic ores, which enabled ores of 2 percent to 3 percent copper content to be exploited profitably, whereas previously the break-even point had been nearer 10 percent. However, the ratio of ore to fuel required in these processes favored preliminary on-site treatment of ores, and so Britain increasingly became the destination for partly smelted ore known as "regulus," which required only the final stages of smelting. More significant still was the successful adoption of the Bessemer process in copper smelting. Not only did this reduce significantly the overall fuel-to-ore ratio, but it also dispensed with the large number of furnace stages required in the smelting process. Together, these factors removed the economic and technological advantages held by British copper smelting companies, and eventually the widespread introduction of the Bessemer process led to full smelting taking place at or near copper mines in other countries and consequently to the rapid decline of exports of ore and regulus to Britain. This, together with the collapse of the Cornish mining industry in the 1860s and 1870s, signaled the end of the British copper smelting industry, which was almost extinct by the early 1920s. Thus, within a period of 230 years, a small British industry had both
grown to international prominence and succumbed to international competition as technological change removed the comparative advantage Britain held over other smelting locations.

Copper Smoke

Throughout the history of the British copper smelting industry, atmospheric pollution proved to be a contentious issue. This is not surprising, since smelter smoke has caused concern in many places where metals have been manufactured. Historical studies have highlighted the problem in 19th-century Spain, Germany, and the United States. In Britain, the Swansea region was singled out in a national geochemical survey as having been particularly affected by atmospheric pollution, not only from the copper industry but also from the numerous other metal works that operated in the area.6

Until its decline, the copper industry was the principal contributor to Swansea's pollution problems, and "copper smoke"—a cocktail of noxious vapors and particles given off by ores when smelted, mixed with coal smoke from furnace fuel—was acknowledged as one of the most potent forms of industrial pollution in Britain. As most copper ores, and Cornish ores in particular, had a high sulfur content and often contained fluorspar, copper smelting produced strong concentrations of the toxic gases sulfur dioxide and hydrogen fluoride, which reacted with moisture in the air to form sulfurous (H2SO3), sulfuric (H2SO4), and hydrofluoric (HF) acids. This has led one historian to describe copper smoke as "the 'acid rain' scandal of its day."7 But acid rain was not the only problem. The smoke itself was frequently inhaled by furnace workers and the local population; moreover, particles of copper, sulfur, arsenic, lead, antimony, silver, and other pollutants found in copper ores were deposited on the


surrounding countryside. This dry deposition probably had a more serious effect on the local environment than the acid rain.

This is not to suggest that Swansea was constantly shrouded in a pall of smoke. As one observer noted early in the 19th century, "the idea of it [Swansea] being impregnated with smoke from the copperworks is an unfounded prejudice." Indeed, the town was able to function both as a location for heavy industry and as a fashionable seaside resort. But as the century progressed, the town became more industrialized, and the pollution problem worsened as the volume of copper smoke increased and was discharged over a wider area. Elsewhere in Britain, Llanelli, Liverpool, Tyneside, Anglesey, and Hayle were also affected by fumes from local copper smelters, and copper smoke compounded the severe pollution problems of St. Helens, which also suffered from high levels of atmospheric pollution from alkali and other industrial works.

The scale of the pollution is hard to quantify. A pair of travelers commented wryly that in Swansea the smoke ascended "not in 'volumes,' but in 'encyclopaedias,'" as portrayed dramatically in figure 2. More scientifically, the French sociologist Frédéric Le Play, in an earlier career as a metallurgist, calculated in the mid-1840s that about 92,000 tons of sulfurous acid was projected into the atmosphere annually by Swansea smelters. In comparison with other available data, this output from copper works alone is approximately equivalent to the sulfur dioxide emission from all industrial and domestic sources in London in 1814 (when the damaging effect of coal smoke in the capital was already notorious) and is just under half the total for the city of York in the early 20th century. A study of the Llanelli Copper Company by Newell and Watts shows that the output of atmospheric pollution from the company's works in the 1860s was exceptionally high and spread over a large area, covering south Wales and beyond. The output of pollutants from these works alone would be regarded as serious by today's safety standards. For instance, estimated emissions of the heavy metals lead, arsenic, anti-

---

12The author is grateful to Peter Brimblecombe for this information.
FIG. 2.—Swansea: town and harbor, circa 1881. This lithograph shows clearly the volume of copper smoke produced by copper works in the Swansea Valley. Unusually, the wind is blowing from the east. The bleakness of Kilvey Hill, on the right hand side of the picture, is apparent. (Courtesy of Swansea Museum.)

mony, and copper within about 7 miles of the works were in the range of 10 to 15 micrograms per cubic meter annual average. A recent European Community regulation has set a limit of 2 micrograms per cubic meter, with anything above 1.5 micrograms per cubic meter seen as a health hazard. When the contribution of other smelting works, other industries, and the domestic burning of coal are taken into account, it is clear that the Swansea region suffered from severe atmospheric pollution.

_Early Problems_

For as long as there are records of copper smelting in Britain, there have been reports of complaints about copper smoke. Problems were noted when the Mines Royal Company first established copper smelting in south Wales in the late 16th century. When the copper industry revived in Swansea in the early 18th century, it soon led to disputes which resulted in the prohibition of further works

inside the borough. This policy of "zoning" industrial polluters continued, and when the lease of the Old Copper Works in Swansea ran out in 1764, the new lease acquired from the borough included a restrictive covenant prohibiting the use of the building for smelting copper or lead. In the same year, a similar covenant appeared in a lease drawn up between landowner Sir Roger Mostyn and the copper smelter and manufacturer Thomas Patten. The lease permitted Patten to build manufacturing works on Mostyn's land in the Greenfield Valley, north Wales, but prohibited "the grinding of corn, malt or other grain and the smelting of copper ore or smelting or refining of any other mineral or metal that is sulphurous and may be hurtful to man or beast or destroy the trees of Sir Roger Mostyn now growing thereto, in Greenfield."

Four years later a complaint about copper smoke appeared in a letter to the *Liverpool Chronicle*. This referred to the activities of William Roe's Macclesfield Copper Company, which, in 1770, became involved in the first known court case concerning copper smoke. The company was indicted for public nuisance by the Liverpool Corporation and forced to relocate its smelting works outside the town. Another early reference to copper smoke dates from 1796, when the manager of the Mines Royal Company's Gnoll Works at Neath reported that "Lady Mackworth objects to sign the lease" for fear of damage to her house from copper smoke, despite the fact that she owed part of her family's wealth to copper smelting at these works. And when John Vivian, smelter and the father of John Henry

---

14 For the earliest instance of copper smoke, see D. J. Davies, *The Economic History of South Wales prior to 1800* (Cardiff, 1933), p. 70. Two incidents in the 1720s are reported in Geraint D. Fielder, "Public Health and Hospital Administration in Swansea and West Glamorgan since the end of the 18th Century to 1914" (master's thesis, University of Wales, 1962), pp. 283–86. Grant-Francis also notes that Lockwood, Morris and Company's move from the Llangavelach Works to the Forest Works in 1727 may have been because of the problem of copper smoke. George Grant-Francis, *The Smelting of Copper in the Swansea District of South Wales, from the Time of Elizabeth to the Present Day*, 2nd ed. (London, 1881), p. 110.


18 Grant-Francis, p. 77.
Vivian, established the Hafod Works in Swansea in 1809, he received notice from Rowland Prichard, a local landowner, that "I shall commence an Action against you for the injury that may be done to my Estate . . . by the said Works in the Smelting or Manufacture of Copper," although no documentation of such an action has come to light.

As the industry expanded from the 1820s, such isolated reports were replaced by a series of complaints and court cases. Overall, the copper smoke problem manifested itself in three ways: first and foremost, as a private nuisance through damage to individuals' land and livestock; second, as a public nuisance; and third, as a public and occupational health issue. In turn, these concerns prompted responses from various parties, at the local and national government levels, through public debate and activity, and by legal action. As will be shown, only the last of these posed a serious threat to smelting companies, although a desire to maintain good public relations may also have induced smelters to take action. On their part, smelting companies responded in three ways to the problem: some did nothing, others made out-of-court settlements with those whose property was affected, and a few turned to technological solutions, either to reduce the level of emissions or to recover pollutants as marketable by-products.

Pollution and Public and Private Nuisance Law

In law, private nuisance refers to the unreasonable interference with another's use or enjoyment of his or her land, and public nuisance is that which obstructs or causes inconvenience or discomfort to the public. Awareness of potential legal action over nuisance and the early intervention of the local corporation to zone industry ensured that smelting works in Swansea were located on the eastern edge of the town so that the prevailing westerly winds blew the smoke across wasteland. However, northerly and northwesterly winds frequently brought smoke across the town, and places farther up the Swansea Valley, such as Llansamlet and Morriston, were often affected (see fig. 3). In Neath, copper smoke was probably less of a problem given the location of the smelting works, but the works in and around Llanelli were less favorably situated to the south and to the west, so that its population was at greater risk. When the wind

20 The dispersion of copper smoke in south Wales is referred to in BPP, Second Report of the Commissioners for Inquiring into the State of Large Towns and Populous Districts 18 (1845), p. 268; H. W. E. Davies, "The Development of the Industrial Landscape of Western South Wales during the Nineteenth and Twentieth Centuries" (master's
was in the right direction, inhabitants could be forced to breathe in fumes which caused "a dry sensation in the throat, a tight feeling across the chest, [and] watering and smarting of the eyes." The most striking feature of copper smoke, however, was its impact on vegetation. The following description, written by Daniel Webb in 1812, is typical of those made by travelers who passed by smelting sites: "about a mile or two towards the entrance of Swansea, the appearance is frightful, the smoke of the copper furnaces having entirely destroyed the herbage; and the vast banks of scoriae surrounding the works, together with the volumes of smoke arising from the numerous fires, gives the country a volcanic appearance."
The damp atmosphere and high levels of rainfall made acid rain a problem in the towns, as could be seen from its effects on stone and paintwork and the discoloration and corrosion of windows. Its effect on vegetation could be devastating and almost instantaneous. As one farmer complained, "it shrivels up the grass and the straw almost as if a dash of lightning had gone over it." Land in close proximity to the copper works affected by both acid rain and the dry deposition of pollutants, such as the western side of Kilvey Hill in Swansea, was often completely denuded (see fig. 2). The grass *Melica coerulea* was even regarded as a botanical curiosity, as it was the only plant that could withstand copper smoke near the Amlwch works on Anglesey. At greater distances from copper works the concentration of smoke was diluted and the damage less severe, but the effects of acid rain and dry deposition of pollutants were still noticeable. It was claimed that animals grazing within a radius of several miles of certain works suffered poisoning from arsenic, and there were frequent complaints about "smoke disease," or *efrydd-dod*, the symptoms of which were swollen joints and rotted teeth, which would eventually kill the animals unless they were removed to better pasture. Such was the extent of damage caused by copper smoke that landowners in Cornwall often forbade any preliminary on-site smelting of copper ores in mineral leases granted to mining companies.

Copper smoke was clearly an inconvenience to many. In legal terms, the general effect on the community left smelting companies open to indictment for public nuisance (as with the Macclesfield Copper Company), while damage to individuals' property made companies liable to private nuisance actions. Given the repeated evidence of copper smoke damaging property, it might be supposed that smelting companies constantly faced legal actions which they found difficult to defend. This was not so. To begin with, local attitudes toward the industry limited the number of potential plaintiffs. Furthermore, many victims of the damage were discouraged from taking legal action because of the high cost and low probability of bringing a successful lawsuit against a firm.

---

25 *Cambrian*, August 6, 1858. For the effects of copper smoke on buildings, see BPP, *State of Large Towns*, pp. 268, 273.


23 For example, see Rees, "Copper-Smoke Dispute" (n. 4 above), p. 483; and Williams, p. 27.

With regard to local attitudes, many accepted that copper smoke was an inconvenience that had to be tolerated if it could not be practically or economically remedied. Certainly in the Swansea district, many who suffered the effects of copper smoke owed their livelihood directly or indirectly to the copper industry and were prepared to accept its less attractive aspects. This sentiment is expressed in the "Song of the Copper Smoke," which includes the lines:

I touch the tall trees with my vapoury hand,  
And their leaves drop off, like courtiers bland. . . . 
You may search the vale and the mountain high  
There is not a flower to gladden the eye.

But it ends with the verse:

The widow's lone bosom I thrill with joy  
As I fill the hands of her orphan boy, 
The miner I help in the sunless cave;  
By me rich merchants their fortunes save; 
Barristers, bankers, and even clod-hoppers 
Would feel very small if they hadn't "some coppers."

Those who perhaps suffered the most personal discomfort from copper smoke were employees of copper works and others living in industrial communities near the works, such as Morriston and Vivian Town, but no reports have come to light to suggest that copper smoke was ever the subject of industrial action on their part. Others badly affected were landowners and farmers with land on the outskirts of the town. Of these, the farmers were the more active complainants against smelting companies. The more influential landowners had substantial interests in local industry and would have been reluctant to involve themselves in disputes that threatened the existence of industrial works. When asked if his landlord, the earl of Jersey, was concerned about the damage to his agricultural land, the smelter Pascoe Grenfell commented, "I do not believe Lord Jersey would give you a shilling to get his farm back, because his colliers [which supplied the copper works] and cottages for colliers and others pay him fifty times as much as the land. . . . I should think that one week of his royalties from coal would pay all his agricultural rent for the year from Llansamlet." Nevertheless, the earl was involved in several disputes with smelters to obtain compensation for

27 The Tourist's Companion in Swansea (Swansea, 1871), pp. 5–6.  
damage to his land, which will be described later, although there was no question of his seeking an indictment against the offending companies to put them out of operation.

The Swansea Corporation, which could have indicted smelting companies for public nuisance, limited its involvement initially to influencing the location of the industry in its early years. Although the corporation sought to promote Swansea as a seaside resort, it did not allow this to conflict with the development of industry, which was seen as the backbone of the local economy.29 This favorable attitude toward the copper industry was further apparent in 1820, when a senior officer of the corporation was petitioned to convene a meeting of inhabitants to discuss measures to curb the smoke problem that were "consistent with the prosperity of the copper works."30 In October of the following year, a fund was established "for obviating the inconvenience arising from the smoke produced by smelting copper ores." In total, just over £1,000 was raised, of which about one third came from the subscriptions of landowners, nearly half from those with interests in copper smelting (including the Vivians, who donated £200). The Swansea Corporation itself subscribed £200. The committee managing the fund resolved that a reward of £1,000 should go "to that person who, in the most satisfactory manner, shall destroy the noxious qualities upon the whole process, and at the same time effectuate the greatest reduction of the Bituminous Smoke." Four processes were short-listed. Both John Henry Vivian and Bevington Gibbins (of the Rose works) submitted systems of flues for condensing gases, William Young of Cadoxton submitted a furnace with an extended flue and wood fire at the end to burn sulfur, and a design by William Williams failed to be presented for the final assessment. None of these designs fulfilled all of the requirements for the award, although Vivian's process (which will be described later) was strongly commended by the judges.31

The fund and competition—a curious mixture of 19th-century philanthropy, scientific endeavor, and industrial paternalism—proved to be the only significant public initiative taken over copper smoke. It coincided with a court case in which Vivian and Sons were indicted for nuisance by local landowner Mansel Phillips. However, Phillips dropped proceedings, apparently in response to Vivian and Sons' efforts to deal with the output of copper smoke.32

30Quoted in Rees, "Copper-Smoke Dispute," p. 483 n.
31Proceedings of the Subscribers to the Fund for Obviating the Inconvenience Arising from the Smoke Produced by Smelting Copper Ores (1863), pp. 11–14; Cambrian, February 11 and 22, 1823.
32Rees, "Copper-Smoke Dispute," p. 483 n.
In the absence of local authority involvement, legal action was left in the hands of private individuals such as Phillips. Those who took smelting companies to court faced a number of difficulties. First, the onus was on the plaintiff to prove that damage caused to his or her property was the result of pollution from a particular source. In practice, identifying a single source proved difficult in areas where there were several copper works (as in Swansea) or where other polluters, such as chemical works, were in close proximity (as in St. Helens). Second, to achieve an unambiguously successful prosecution the plaintiff either had to prove that the entire damage to his or her property was the result only of copper smoke or had to provide evidence of the extent of the damage caused by smoke. Again, the practical difficulties of doing so were great.

More generally, studies by Brenner and McLaren argue that nuisance law became increasingly ineffective in dealing with pollution associated with rapid industrialization. At the time, they claim, the law of nuisance was not normally regarded as a way of obtaining compensation from polluters but was seen as a means of eliminating the source of pollution by injunction (although the instances of damages being awarded in copper smoke cases outlined below suggest this may be an exaggeration). Both Brenner and McLaren contend that during the 18th century, the law favored the plaintiff, particularly in nonindustrial areas where offending works were recently established. In a private action, the plaintiff could claim “prior appropriation” of the land for agricultural purposes, forcing firms to move elsewhere. Similarly, in a public nuisance action, local authorities were in a strong position to force the relocation of works and hence effect the zoning of industry within the locality. However, according to McLaren, this degree of protection broke down in the early 19th century. In the absence of a large number of court cases, and with rapid industrialization, it seems that the courts became strongly influenced by arguments about the economic benefits of industry to the wider community and less well disposed to private nuisance actions. The concept of reasonableness became firmly established; it was deemed reasonable for individuals to put up with a certain degree of discomfort from pollution for the sake of the general economic benefit of industry to the community. The zoning of industry reinforced this view, and once industry became firmly established in a part of town (as was the case with the copper works

in Swansea), it became increasingly difficult to prosecute firms unless they acted in a way to worsen or spread pollution. In such cases, the onus was on the plaintiff to prove that conditions had deteriorated, which again proved difficult in practice.

This point is illustrated by the opinion of a lawyer, in a copper smoke nuisance case of the 1890s, who summarized the problems faced by those taking smelting companies to court: "The claimants will know that the Defendants will fight to the death[,] that success will cost them a lot of money and that failure will ruin them and they know that any jury will be very slow to find in their favor." 34

Newspaper reports and evidence presented at parliamentary inquiries suggest that while there were at least twenty or so court cases concerning copper smoke during the 18th and 19th centuries, in only five instances was the plaintiff unambiguously successful: when the Liverpool Corporation indicted the Macclesfield Copper Company for public nuisance in 1770, and in the cases of Earl of Jersey v Tennant; Earl of Jersey v Williams (1841); Houghton v Bankart (1858); and Tipping v St. Helens Smelting Co. (1865).

Little is known of the Earl of Jersey's first action, except that as a result of the ruling, Bankart and Sons of the Red Jacket works, Neath, paid the earl, who was their landlord, "a rent of £5 per furnace per annum," indicating success on the part of the earl. He was also successful in his action against John Williams, presumably seeking damages against the defendant's firm, Williams, Foster and Company, which was the largest in the industry. Mention is made of the earl's involvement in a third lawsuit, against Pascoe Grenfell and Son in the 1850s, although the outcome of this is unclear. The award of £450 in damages to Dougdale Houghton against Frederick Bankart, of the Red Jacket works, is the only known instance of a tenant farmer in south Wales obtaining substantial compensation for damage to his property. In this case, Houghton, who was also a land agent in Birmingham, took over the tenancy of two farms adjoining the copper works in 1853. Shortly afterward, the copper works were extended, and the copper smoke problem worsened considerably, causing extensive damage. The defense was unable to convince the special jury that the escalation in damage was caused by copper smoke drifting several miles eastward from Swansea rather than a matter of yards from the Red Jacket works. 35


35 For Earl of Jersey v Bankart and Sons, see Cambrian, August 6, 1858; for Earl of Jersey v Williams, Foster and Co., see Jones (n. 19 above), p. 314, and Cambrian, January 23, 1841; for Earl of Jersey v Pascoe Grenfell and Son, see Jones, p. 314; and for Dougdale Houghton v Bankart and Sons, see Cambrian, August 6 and 13, 1858.
Tipping v St. Helens Smelting Co. is of special interest. William Tipping, a wealthy landowner, purchased the 1,300-acre Bold Hall estate in St. Helens in 1860. At the time of purchase, Tipping was aware that copper works were being erected on adjoining land. Once the works were operational, Tipping's land was damaged by copper smoke readily identifiable as coming from these works. Despite the fact that he had moved to Bold Hall knowing that damage to his property was likely, Tipping brought an action for damages against the smelting company on two counts: first, for injury to trees, hedges, fruit and cattle; and second, for severe personal discomfort. Tipping was awarded damages, and on appeal the House of Lords upheld the decision on the first claim of damage to property but not on the second claim of discomfort. Tipping then obtained an injunction against the copper company, which was forced to close its works and relocate elsewhere in St. Helens. Despite Tipping's victory, the House of Lords's ruling was significant, as, according to legal historians, it made successful nuisance actions on grounds of discomfort "virtually impossible in the industrial midlands and regions such as Swansea and Cardiff."36

Perhaps the best known of the south Wales nuisance cases was the "Great Copper Trial" of David v Vivian at the Carmarthen Assizes in 1834. Thomas David represented a group of eleven tenant farmers from the village of Llansamlet who, with the help of Merthyr Tydfil solicitor William Meyrick, had formed a club to indict Vivian and Sons for public nuisance. It was decided to bring the action in Carmarthen, as it was felt that no jury in Glamorgan would return a verdict against a copper smelter. In his summing up, the judge stated that the distress of a handful of farmers did not constitute the public nuisance required for an indictment against the company, and the jury returned a verdict of not guilty. The Swansea newspaper the Cambrian reported that the news of the verdict "has diffused the greatest joy throughout this town and neighbourhood, which has been manifested by the ringing of bells and the firing of cannon throughout the day."37 The Carmarthen verdict did not deter the farmers. In the following year, David brought an action for damage to his land against Pascoe Grenfell and Son at the Breconshire Assizes, this time seeking financial compensation.38 In coming to its verdict, the jury acknowledged that the plaintiff had suffered smoke damage to his land, but it attributed the poor quality of David's land

37Cambrian, March 9, 1833. See also University College Swansea, Yorkshire Imperial Metals, Vivian Papers D1, Brief for the Defendants.
38Cambrian, August 9, 1834.
primarily to bad management. Without proof of the degree of damage attributable only to copper smoke, the plaintiff was awarded nominal damages of one shilling. This was something of a Pyrrhic victory for the farmers, for although it kept open the possibility for further legal action, the emphasis on the culpability of the farmer through bad management made future success unlikely. Indeed, it seems the farmers took no further action.

Smelting companies could nevertheless be sympathetic toward what they considered to be reasonable complaints of damage and were prepared to consider ways of compensating victims out of court. In the buildup to the first major dispute involving Vivian and Sons in the 1820s, John Vivian readily acknowledged culpability in damaging property and suggested that an independent referee be appointed to determine the level of compensation his firm should pay. Vivian feared that legal action could lead either to the enforced relocation of his works or the setting of excessively high levels of damages, which could put the firm out of business. In the event, Vivian’s offer of arbitration was rejected, and the firm successfully defended the legal action brought against it, in spite of Vivian’s earlier admission. But entering into private arrangements had its disadvantages. By making such arrangements firms effectively admitted liability, which would normally increase the probability of legal action being taken by those seeking compensation, who would now be relatively sure of their success. It might also encourage others in the locality to bring charges. For instance, in about 1840, Newton, Keates and Company of St. Helens faced complaints of damage to land by a group of local farmers. To avoid lawsuits, the company made an arrangement with the farmers to appoint an assessor to fix levels of compensation. Eventually, the arrangement broke down, and legal action followed. This action may have opened the way for further disputes, as there are more reported complaints against this company than any other. The lack of references to similar compensation arrangements may be a result of the scarcity of extant copper smelting records, or it may reflect an unwillingness on the part of companies to risk the sort of problems apparently faced by Newton, Keates and Company.

Later, in south Wales, a different type of arrangement was entered into. Following an assessment that showed that the value of agricultural land in smoke-affected districts had fallen by half, local landowner Nash Vaughan (chairman of an association formed by land-

---

39Vivian Papers A782, National Library of Wales, Aberystwyth.
40In one assize, the company had as many as fifteen actions brought against it. BPP, Royal Commission on Noxious Vapours (n. 28 above), pp. 156–57, 503.
Atmospheric Pollution and the British Copper Industry

owners to press smelting companies to deal with copper smoke) took legal action in 1866 against the English Copper Company. Eventually the company agreed out of court to install apparatus at its Cwmavon works in Port Talbot similar to that used by Vivian and Sons to curb copper smoke emissions. However, Vaughan died suddenly, and the new equipment fell into disuse. The Cwmavon works were later taken over by the Rio Tinto Company, which also failed to use the new furnaces. Following a further assessment of land values, Miss Emily Talbot, who had recently inherited the Margam estate, was forced to reduce her tenants' rent by between 35 and 75 percent in 1893. In response, she took out an injunction against the Rio Tinto Company, a move that caused a major outcry as it threatened the employment of many in the Port Talbot district. The injunction was withdrawn in exchange for damages of a lump sum of £1,400 and an annual payment of £700, an arrangement that led immediately to a further lawsuit brought against the company by Messrs. Morrison and Rees, a local landowner and his tenant at Tonmawr Farm. In this case, the plaintiffs were unsuccessful, being unable to prove that the amount of damage caused to their property had increased over the past twenty years.41

To summarize, the law offered little protection against or compensation for the effects of copper smoke. Although a few successful actions were brought against smelting companies (by those who could afford to do so), the copper industry was associated with bringing prosperity to the Swansea region and the country as a whole and was therefore regarded favorably in the courts, where it became increasingly difficult for plaintiffs to achieve success in nuisance cases. The early zoning of the industry also meant that by the 19th century copper smoke had become acceptable in certain areas under the principle that "what would be a nuisance in Belgrave Square would not necessarily be one in Bermondsey."42 As a consequence, while the possibility of legal action was an ever-present concern to copper smelters, successful prosecutions were rare.

Technology

Despite the limited success of legal action against smelting companies, a number of firms did invest (some quite heavily) in methods to deal with copper smoke. It would appear, however, that the driv-

41 For the dispute concerning Nash Vaughan, see Cambrian, September 15 and October 27, 1865; and Rees, "Copper-Smoke Dispute" (n. 4 above), p. 492. For the later dispute, see Important Correspondence with Miss Talbot (Swansea, 1894); RTZ, 90-A-3; BPP, Report of the Royal Commission on Land in Wales and Monmouthshire 37 (1894), pp. 394, 492–93.

42 Quoted in Brenner (n. 33 above), p. 414 n.
ing force had less to do with altruistic motives than with the desire to reduce the potential threat of legal action, to comply with legal requirements, and, perhaps most important, to benefit economically from the recovery of by-products that otherwise quite literally went up in smoke.

The earliest and most widely used technology involved constructing tall chimney stacks to which all or most of the furnaces at a copper works were connected by long flues. Some of the arsenic, sulfur, and hydrofluoric acid would condense in the flues and the stacks as the smoke cooled, and that which passed out of the stacks was dispersed more widely. Materials collected in the flues could be used to produce by-products, such as arsenic and sulfuric acid.

Commercial interest in recovering sulfur during copper smelting was first shown in the late 18th century. During the 1770s, the Bristol industrialist John Champion Jr. entered into partnership with William Roe of the Macclesfield Copper Company to recover sulfur during the initial process of smelting known as calcination, in which the majority of the sulfur was expelled. Their Brimstone Company processed ore mined on Anglesey under the following terms with the mining companies. The Brimstone Company was permitted to erect calciners on the mine site at an annual rent of £50. The mining companies supplied Brimstone with ore from which sulfur was extracted, and Brimstone returned the processed ore to the mining companies. In this way, the two commercial operations were kept separate. The Brimstone Company had complete control over the production and sale of sulfur while the mining companies benefited from having ore that was cheaper to transport to smelting works because of its reduced bulk and was easier to smelt because of its lower sulfur content. The process used on Anglesey has been described by Joan Day, who suggests that it may have been used at an earlier date by copper smelters in the Bristol area. It would seem, however, that the costs of the process and the low price of sulfur meant the process was not a commercial success, although the fate of the Brimstone Company itself is not known.

A similar method to that used on Anglesey was adopted and improved by John Henry Vivian at the Hafod works in the 1820s. Vivian's initial scheme also incorporated water showers placed in the flues and in chambers connected to the flues to increase the rate at which the gases condensed, although the company later stopped us-

---

Atmospheric Pollution and the British Copper Industry

ing the showers, claiming that "the use of water was not so essential as it was first thought." This method of treating copper smoke received much publicity, being associated with the competition held in Swansea in the early 1820s "for obviating the inconvenience arising from the smoke produced by smelting copper ores." It also attracted the attention of some of the most eminent scientists of the time. Sir Humphry Davy showed interest in Vivian's experiments, and Vivian employed Michael Faraday and Richard Phillips to conduct tests on the equipment, providing an interesting example of the use of applied science in industry. It is not surprising that with this backing, and having invested more than £6,000 in the equipment, Vivian's method was recommended to other smelters by the committee of the competition as the best means of dealing with the problem. The project, which demonstrated Vivian's ability to apply scientific principles to industrial processes, also helped the smelter to be elected to a prestigious Fellowship of the Royal Society. Other companies adopted this method (with or without the addition of showers), and some of the constructions were extremely large and expensive, notably those built at the Llanelli, Pembrey, Spitty, and Cwmavon works. The first of the Llanelli Copper Company's two large stacks, completed in January 1831, was 230 feet high, the Pembrey stack was 270 feet high, and the second Llanelli stack, built in 1861 and known as Stac Fawr ("Big Stack"), was 320 feet high.

In 1832, a lease drawn up between the Borough of Avan, Port Talbot, and John Vigurs for the establishment of what eventually became the Cwmavon works even stipulated that a chimney approved by engineers had to be erected "for the purpose of condensing or removing the injurious properties of the smoke or effluvia." Eventually, a system was constructed whereby forty-two furnaces were connected to a flue nearly a mile long that ran up the side of a large hill to a stack, the top of which was at a height of more than 1,000 feet. Further interest was also shown about this time in dealing with copper smoke on Anglesey, presumably along similar lines. In a let-

44 Proceedings of the Subscribers (n. 31 above), pp. 11–12; and BPP, Royal Commission on Noxious Vapours, pp. 464–65.
47 For the first Llanelli stack, see Cambrian, February 12, 1831; for the Pembrey and second Llanelli stacks, see Cambrian, November 1, 1861.
ter to the manager of the Mona Mine Company, a "discovery" for condensing smoke was discussed, and its author noted, "That the discovery is an effectual one condensing the sulphur, and many other noxious substances, I think has been proved, by there not being a single complaint by any of the farmers since it was first applied, now full 2 years, and by another proof of my having a field of wheat close by the foot of the mountain."49

This method of control, which was used in a variety of metal works, certainly prevented high levels of damage in the immediate vicinity of the works, but it failed to eliminate the smoke problem. Sulfur dioxide emissions were hardly reduced, and the tall stacks increased the area affected by pollution. The Swansea smelter Pascoe Grenfell realized the implications of spreading pollution and refused to build large chimneys, believing it could lead to more rather than fewer legal disputes.50 Vivian and Sons certainly faced a major court case in 1833, just after increasing the number of stacks and flues at the Hafod works; the actions brought against the Cwmavon works by Nash Vaughan and Emily Talbot followed the construction of its apparatus, and Vaughan's estate was more than 7 miles away from the Cwmavon works.

John Henry Vivian and others recognized in the 1820s that the copper smoke problem might best be tackled by improved furnace technology.51 Most copper smoke was produced in the first process of smelting, known as calcination, which was used to remove large amounts of sulfur. It was argued that it was theoretically possible to conduct this process and at the same time oxidize the sulfur driven off the ore to produce sulfuric acid in the furnace, thus eliminating sulfuric gas emissions at source. The chemistry was understood, but developing the equipment was another matter. The basic problem was that the oxidation necessary to produce sulfuric acid was prevented in existing furnaces by the presence of coal smoke. The challenge was therefore to develop a commercially viable furnace that could keep the fumes emitted from the ores separate from the smoke given off by furnace fuel. Various attempts were made to overcome this problem. Pascoe Grenfell and Son went as far as installing furnaces designed by Herr Schafheutl of Munich in 1848 and employing a process devised by Adolph Gurlt of Birmingham

50BPP, Select Committee on Noxious Vapours (n. 7 above), p. 577.
Atmospheric Pollution and the British Copper Industry in the 1860s, but both failed to work satisfactorily and were abandoned.52

Despite the technical difficulties, two types of furnace were devised that could overcome the problem, and both were used commercially to a limited extent from the 1860s. The first to be developed was the muffle furnace, which kept the copper smoke fumes separate from the coal smoke by heating the ore, which was laid out on a flat bed, from underneath the bed, there being no direct contact between the ore and the heat source. This furnace was favored by the smelter Peter Spence, who went on to use his own patented design in the Goole Alum and Smelting Works. Versions of the muffle furnace were also used by Charles Lambert at the Port Tennant Works in Swansea and by Newton, Keates and Company in St. Helens.53 The second type of furnace, developed by Moritz Gerstenhöfer in Germany, where smelter smoke was also becoming a serious problem,54 produced very little coal smoke, as it required fuel only to begin calcination. Once ignited, the furnace used the sulfur in the ore as fuel, thus eliminating the presence of coal smoke and indeed significantly reducing the amount of coal required in calcination. Vivian and Sons purchased the British patent for the Gerstenhöfer furnace,55 which received highly favorable reports in the Times as well as the local press, being hailed as the solution to the copper smoke problem.56

The encouraging publicity was brought about to a large extent by a pamphlet entitled “On the Improvement of Swansea: Suppression of Copper Smoke,” written by a prominent and influential Swansea figure and friend of the Vivians, George Grant-Francis.57 Such claims were premature, however, as in practice both types of furnace had major limitations. At best the furnaces could remove only 33 to 40 percent of the sulfur, and neither furnace was suited for smelting ores of less than 20 percent sulfur content; indeed, the Gerstenhöfer furnace could not operate with a lower proportion of sulfur. This limited the applicability of these to a smelting industry that by that time was handling an increasing quantity of imported ores with a

52For Schafheutl, see Percy (n. 11 above), pp. 340–41; for Gurlt, see Grant-Francis (n. 14 above), p. 123, and Cambrian, October 27, 1865.
53BPP, Royal Commission on Noxious Vapours (n. 28 above), pp. 503, 507–8. For details of the muffle furnace, see BPP, Select Committee on Noxious Vapours, pp. 123–26; and Chemical News, suppl., September 20, 1867.
54Schramm (n. 6 above), pp. 196–209.
55BPP, Royal Commission on Noxious Vapours, p. 470.
56Times (London), August 21, 1865.
57Reproduced in Grant-Francis, pp. 151–60.
low sulfur content. Furthermore, the furnaces were particularly expensive to install, as was the other equipment required for sulfuric acid manufacture, such as lead chambers, steam boilers, concentrating pans, and stills; moreover, the Gerstenhöfer furnace could calcine only finely ground ore, which meant further expense for costly crushing equipment.58

In the main, the profitability of sulfuric acid as a by-product of copper smelting was questionable. As a bulky, low-cost good, sulfuric acid could be sold profitably only to local buyers. In Swansea, the scope for selling acid was very limited, the principal users being tinplate manufacturers who required the acid for "pickling," or removing scale and impurities from sheets of iron prior to plating.59 Vivian and Sons also opened superphosphate fertilizer works and alkali works to utilize the acid. At Lambert’s Port Tennant works, the acid was used in the manufacture of copper sulfate, but Lambert regarded this enterprise as a loss-making failure. Pascoe Grenfell decided not to introduce similar apparatus, as he felt it was not worth the expense.60 Thus, only three of the eleven Swansea companies and one of the six Lancashire companies introduced the new furnaces at their works. The technology portrayed as solving the copper smoke problem therefore had very little impact overall on the industry.

The last technological advance employed to deal with copper smoke, and other metal fumes, was to pass an electrical current through flues linking furnaces to chimneys to increase the rate of precipitation of pollutants. References to experiments using this method date from 1886, although it was not until after World War I that it was adopted to any great extent. By this time copper smelting in Britain was in rapid decline, and so electrical precipitation had little opportunity to benefit the industry. However, it should be noted that Vivian and Sons were again early users of this technology, enhancing the company’s reputation as that which paid greatest attention to the copper smoke problem.61

Public Health, Sanitation, and Factory Legislation

Health, sanitation, and factory conditions were issues of major public concern in Victorian Britain. The copper industry came un-
Atmospheric Pollution and the British Copper Industry

Under the close scrutiny of official bodies appointed to investigate such matters but successfully evaded all attempts to deal with its pollution problem through legislation. The industry's escape from control was the result of a combination of lack of concern regarding the effect of copper smoke on health and the perceived high cost of imposing regulations on the smelting process.

Copper Smoke and Health

Today, smelter smoke is recognized as a serious occupational and public health hazard. Regular exposure to copper smoke would undoubtedly have had serious chronic effects on workers and the local population given the toxicity of the constituent gases and dust. However, despite the fact that the earliest continental publications on industrial hygiene dealt with metal mining and smelting, the health risks of copper smoke were barely acknowledged, let alone understood, in Britain before the latter part of the 19th century. The slow realization of the toxicity of copper smoke is far from exceptional and is indeed typical of the way in which the hazards of many pollutants have been recognized.

Nevertheless, some observers were concerned with the health implications of copper smelting from an early date. The influenza-like symptoms of "metal fume fever" were recognized as an occupational health problem in 1822 by Potissier, the founding father of modern toxicology. William G. Maton of Penzance, having visited the smelting works of the Cornish Copper Company in Hayle, remarked in 1797: "Nothing can be more shocking than the appearance which the work-men in the smelting-houses exhibit. So dreadfully deleterious are the fumes of arsenic constantly impregnating the air of these places and so profuse is the perspiration occasioned by the heat of the furnaces, that those who have been employed in them but a few months become almost emaciated figures, and in the course of a few years are generally laid in their graves."

Maton's cause was continued by J. A. Paris, another doctor based in Cornwall, but their views received little support, as is made clear in a number of official and semiformal documents. For instance, in

his report on copper works presented to the 1842 Royal Commission on Children's Employment, R. W. Jones noted that copper smoke was a serious problem "upon vegetable and animal life" but that "the inhalation of it does not appear to operate prejudicially upon human health." It was even widely believed that the sulfur in the atmosphere was beneficial to health. In a report presented to the 1845 Commission on Large Towns, William Bevan, a surgeon and registrar at Swansea, argued that copper smoke acted as a prophylactic against contagious diseases, countering the effects of poor drainage and disposal of sewage in the town. Similarly, a Dr. Wilkinson regarded Swansea "as insured from the terrible destructive disease, the Asiatic Cholera," because of copper smoke. Even as late as 1928, the author of an article on the Llanelli copper works was "convinced that these fumes are disinfectant and salutary, although ignorant people have a prejudice against them."

Such views were supported by the much-quoted observation that the average mortality rate in Swansea was lower than for other industrial towns; indeed, it was considerably lower than the national average. This evidence was misleading, however, first because Swansea was not as urbanized as many other industrial towns, where high concentration of population was strongly correlated with high death rates, and second because the overall figure disguised local variations, ignoring possible pockets of high rates of death and disease. It was indeed true that mortality rates in the less salubrious parts of Swansea (where conditions were "unspeakable," according to William Michael, the town's first officer for health) were as bad as anywhere in the country.

66BPP, Report of the Royal Commission on Children’s Employment in Mines and Manufac-
tories 17 (1842), p. 681.
67For Bevan, see BPP, State of Large Towns (n. 20 above), p. 273; for Wilkinson, see Cambrian, July 7, 1832.
69The mean death rate for Swansea between 1841 and 1860 was 19 per 1,000 compared with 22 per 1,000 for England and Wales as a whole. Ieuan G. Jones, Mid-Victorian Wales: The Observers and the Observed (Cardiff, 1992), pp. 26, 171. See also BPP, Third Annual Report of the Local Government Board 25 (1874), p. 440; and Glyn Roberts, The Municipal Development of the Borough of Swansea to 1900 (Cardiff, 1940), p. 48.
70Roberts, p. 48.
However, it took considerable time for such evidence to come to light. For instance, in the 1845 Second Report of the Commissioners for Inquiring into the State of Large Towns and Populous Districts, the geologist Sir Henry De La Beche argued that mortality statistics did not support the view of the benefits of copper smoke expressed by Bevan, but at the same time he could not provide evidence to show that copper smoke was a health problem.\textsuperscript{71} Nine years later, in response to a request for information made to the General Board of Health by the Council of Health of Hamburg, Germany, Thomas Williams wrote an extensive report supporting Bevan’s view of the beneficial effects of copper smoke, stating that it was harmless to workers.\textsuperscript{72}

As the century progressed, the view that copper smoke was harmful gained increasing favor, although expert opinion still varied on the occupational health aspects of copper smelting.\textsuperscript{73} Referring to Williams’s report, the metallurgist John Percy wrote in 1861: “The smoke is an unmistakable nuisance; and the man who pretends it is not, must either have a peculiar constitution or lie under a strange delusion.”\textsuperscript{74} One such person was the smelter Henry Hussey Vivian, who, convinced of the benefits of the sulfurous copper smoke, gave his workers dilute sulfuric acid to drink during an outbreak of cholera, claiming “the very best possible result” in keeping the disease at bay.\textsuperscript{75}

More significantly, increasing awareness of the risks associated with inhaling high levels of sulfur dioxide led to a marked change in opinion presented in official reports. In contrast to its 1842 predecessor, the report of the 1864 Royal Commission on Children’s Employment acknowledged the unhealthy effects of copper smelting upon workers.\textsuperscript{76} Furthermore, a series of studies undertaken from

\textsuperscript{71}BPP, State of Large Towns, p. 279.
\textsuperscript{72}For the request, see Public Record Office, Kew [hereafter PRO], M.T. 13/178. Correspondence between the General Board of Health and Thomas Williams, January 27, 1854; July 18, 1854; and August 9, 1854. For the report, see Williams (n. 21 above).
\textsuperscript{73}This was because of disagreement over the extent to which workers were exposed to fumes that were largely contained within furnaces and flues. Compare, for instance, the contradictory statements by Tatham, who believed copper smelting to be an unhealthy occupation, and Simon and Knyvett, who did not, in Oliver’s classic study of occupational health. Thomas Oliver, ed., Dangerous Trades (London, 1902), pp. 140, 466.
\textsuperscript{74}Percy (n. 11 above), p. 338.
\textsuperscript{75}BPP, Royal Commission on Noxious Vapours (n. 28 above), p. 494. At the time, sulfur was regarded by some experts as a remedy for cholera. Margaret Pelling, Cholera, Fever and English Medicine 1825–1865 (Oxford, 1978), pp. 148–49, 192.
\textsuperscript{76}BPP, Report of the Royal Commission on Children’s Employment 20 (1865), p. 221.
the 1870s by Ebenezer Davies, the medical officer for Swansea, showed that while the villages surrounding Swansea that were particularly badly affected by copper smoke had lower mortality rates than the town itself, they had significantly higher proportions of deaths from acute pulmonary diseases such as croup, bronchitis, pneumonia, and pleurisy. At the time, Davies did not relate these local variations to copper smoke (although he later wrote that he was "assured that the smoke is a source of especial distress to persons sick with pulmonary ailments"). Instead, the connection was made by the medical officer of the Local Government Board, citing Davies's statistics—indicating, perhaps, greater concern for the effects of copper smoke at the national than at the local level.

Despite the growing awareness within the medical profession that copper smoke was associated with such diseases, copper smelting was not considered a serious threat to health, either in the workplace or to the community at large. As a result, copper smelting evaded late-19th-century legislation on "Dangerous Trades," unlike such other industries as lead smelting, where the health risks were more obvious and their effects more acute. Nor was nuisance legislation covering activities "injurious to health" applied to copper smelting. In this case, firm evidence was required that the nuisance caused disease, and it was not sufficient that the nuisance caused discomfort, which was as much as expert opinion on copper smoke was prepared to concede.

Neither did the Swansea Board of Health pay much attention to copper smoke. When Henry Hussey Vivian reopened zinc works in Morriston in 1859, a William Jowett complained that the presence of industrialists on the board diverted its attention away from smelter smoke. The argument could be extended elsewhere. In Llanelli, the smelter Charles Nevill was chairman of the local board of health, for instance. More probably, the absence of an obvious link be-

77 For Davies's work in this field, see BPP, Annual Report of the Medical Officer of the Local Government Board 29 (1878–79), pp. 264–65; Swansea City Archives, Medical Officer's Report (various years); and BPP, Local Government Board 29 (1878–79), p. 259.
82 PRO, M.H. 13/231.
tween copper smoke and disease and the chronic nature of ailments concerned made it a low priority at a time when the board had to face the pressing problems of epidemics and poor sanitation. It is notable that despite his interest in the problem, William Michael made no reference to copper smoke in the officer for health’s report book, which otherwise makes for grim reading about the sanitary condition of Swansea in the mid-19th century.

Smoke and Noxious Vapors

Although knowledge of the health implications of atmospheric pollution increased during the 19th century, the main impetus for legislation in this area came from concern over damage to property. Within the legislation, an important distinction was made between smoke, which was the product of the combustion of fuel, and noxious vapors, which covered other types of harmful or unpleasant gases. The significance of this distinction with regard to copper smoke was made clear in an 1846 parliamentary report on factory smoke prepared by De La Beche and the chemist and politician Lyon Playfair, which stated: “The emission of that which is improperly termed smoke from certain manufactories, such as the copperworks of Swansea, is another question, and involves very different considerations from the prevention of smoke from fuel.” In other words, the “smoke” from copper works was caused not simply by the combustion of fuel but by chemical processes as well. Controlling the emission of what was, in the opinion of experts, a “noxious vapor” caused many more technical problems than controlling coal smoke and was therefore regarded as a separate issue (although at least one attempt was made by a local government officer to deal with copper smoke as “smoke” as well as a “noxious vapor”). However, despite the introduction of legislation covering both forms of pollution, the copper industry largely evaded control.

The development of smoke abatement legislation was both slow and piecemeal. It began with the Smoke Prohibition Act of 1821, which dealt with emissions from steam engines. Coverage was extended in the middle decades of the 19th century by a number of acts of Parliament, conferring on local authorities the power to improve sanitary conditions in towns and cities by enacting antismoke laws and regulations. The 1852 Smoke Nuisance Abatement (Metro-

84 Royal Institution of South Wales, Swansea, R66/187, Report Book of the Officer for Health.
85 BPP, Report upon the Means of Obviating the Evils arising from the Smoke Occasioned by Factories and Other Works in Large Towns 43 (1846), p. 336.
Act related specifically to London's major coal smoke problem, while further national legislation gave local authorities increasing powers, culminating in the 1875 Public Health Act, which allowed all local authorities to introduce antismoke measures if they so desired. Although legislation in this area was limited in scope and impact, it was a response to concern expressed at the local and national levels, and from it developed the guiding principle that "the best practicable means" should be used to minimize the output of pollutants. Legislation on smoke emission contained in the related 1847 Town Improvement Clauses Act and the 1858 Local Government Act was intended specifically for coal smoke. Nevertheless, copper smelting was not included in the list of processes specifically exempted from control by the 1847 act. This omission provided a window of opportunity for William Michael, who, after the passage of the 1858 act, attempted to press the Swansea Board of Health to enforce the law against copper smelting companies on the grounds that copper smoke was composed partly of coal smoke and so came under the ambit of the act. After due consideration, the board accepted the argument presented by copper smelters that such action would conflict with the intention of the legislation given the absence of practicable means to deal with copper smoke, as opposed to unmixed coal smoke, thus reaffirming the opinion of De La Beche and Playfair. There appears to have been no further attempt to apply smoke legislation to copper smoke.

While copper smelters successfully parried legislation on smoke, they also evaded the late-19th-century legislation on noxious vapors. Much has been written about the Alkali Acts of 1863, 1874, and 1881, which provided the first really effective national antipollution legislation, and the two reports that led to them: the 1862 Report of the House of Lords Select Committee on Noxious Vapours and the 1878 Report of the Royal Commission on Noxious Vapours. Although the main purpose of these bodies was to find ways to control noxious emissions from alkali manufacture, which was then the largest branch of the heavy chemical industry in Britain, they also considered in great detail whether or not to recommend control of atmospheric pollution from the production of copper.

The select committee focused principally on the "wet process" of manufacturing copper. This was an adjunct of the chemical industry

86See Clapp (n. 2 above), pp. 32-33.
88See PRO, M.H. 13/178, 1446/59, and 1511/59; and BPP, Select Committee on Noxious Vapours (n. 7 above), p. 73.
and distinct from copper smelting. Wet copper works were located chiefly near chemical works in the north of England. They did not produce copper smoke, since the wet process involved leaching and precipitating copper onto scrap iron from calcined ores soaked in water, but nevertheless noxious vapors were emitted. The committee was chaired by the sometime prime minister Lord Derby, who first raised the pollution question in the House of Lords from a personal interest, having suffered damage to his estate near alkali works at St. Helens (where, according to the historian W. G. Hoskins, "the landscape of Hell was foreshadowed"). Not surprisingly, it was St. Helens that came under the close scrutiny of the committee. This local focus perhaps explains the committee's lack of attention to copper smelting, which was less important than alkali manufacture there.

Despite the attention paid to wet copper production, the first Alkali Act was extremely narrow in its coverage and failed to deal with this trade, concentrating instead on hydrochloric acid emission in the "core" of the alkali industry. However, the second act was much broader and extended the legislation to cover wet copper works. This forced firms to reduce hydrochloric acid emissions by 95 percent, which was made possible by the availability of cheap and efficient technology in the form of the Gossage tower (a device never successfully adapted to copper smelting).


90 Ashby and Anderson, p. 21. During the 1840s, the alkali manufacturer William Gossage developed a strong interest in metallurgy and moved to Neath, where he involved himself with the local metal works. In 1843, he took out a patent with Henry Hussey Vivian for improvements in the smelting of zinc, and in 1845 he patented a method for treating various ores, which included a process for collecting sulfur given off by copper ores using a condensing tower similar to one he had designed previously for condensing hydrochloric acid in alkali manufacture. Although the Gossage tower achieved widespread use in alkali works, it was never taken up by the copper industry. Gossage later complained that he "could not persuade the copper smelters to look at my operations." The reason for this lack of interest is unclear, though it is possible that a condensing tower would have prevented the necessary draft required for efficient smelting obtained by the use of tall chimneys. Whatever the reason, Gossage's lack of commercial success forced him to abandon his activities.
The 1878 Royal Commission, established to consider how legislation on noxious vapors could be extended to other industries and industrial processes, paid greater attention to the smelting of copper, calling many witnesses from the Swansea district. In this respect it focused its attention on the practicability of introducing furnaces that might limit the output of copper smoke. But the evidence presented to the commission showed that this and other recovery methods required the installation of extremely expensive equipment and that profits from the sale of by-products were small. The commissioners worked under the principle that regulation should be introduced only if economically practicable means were available, and they were convinced that this was not the case in the copper industry. They therefore concluded that no controls should be imposed for fear of seriously disrupting the copper trade. However, they did recommend that copper works should be monitored by the inspectorate in the hope that a technological solution to the copper smoke problem might eventually be found.

The decision to exclude copper smelting from the Alkali Acts clearly angered the first alkali inspector, R. Angus Smith. Although he was appointed to inspect workplaces and to ensure that the requirements of the Alkali Acts were met, Smith's interest in atmospheric pollution went beyond the limits of the legislation. He calculated that copper smoke was far more acidic than the noxious vapors of alkali works and was particularly harmful to vegetation because of its high sulfuric acid content. Furthermore, he believed, contrary to the view held by smelters and the Royal Commission, that economically practicable means of treating copper smoke were available in the form of condensing flues and chambers, using technology developed by Vivian and Sons in the 1820s. For these reasons, he felt that copper smelting warranted inspection under the Alkali Acts, a point stressed on several occasions in his annual report. No action was taken during Smith's lifetime, but following further complaints about the copper and other metal industries smelting works became
subject to inspection under the 1906 Alkali Act. Inspection was un-
der the terms proposed in 1878, as a monitoring exercise; no provi-
sion was made to enforce reductions in emissions, owing to the gen-
erally accepted belief in the intractable nature of the problem.94

Conclusion

Despite the seriousness of the problem, copper smoke proved no
more than a minor inconvenience to the business activities of many
smelting companies for most of the 18th and 19th centuries. The
law favored the smelters, with copper smoke regarded as a relatively
small price to pay for the benefits of a thriving industry. If the courts
failed to deal adequately with the problem, so, too, did new legisla-
tion. As technical problems and the high costs of introducing new
technology to control levels of emissions were recognized, legislators
avoided disturbing the status quo for fear of harming the copper
trade, believing there were no “practicable means” to deal with cop-
per smoke. From another perspective, it can be argued that legal
and political mechanisms were unable either to restrict emissions or
to compensate for the considerable social costs associated with the
industry. It must be remembered, however, that at the time evidence
as to the extent of certain social costs, particularly concerning public
and occupational health, was inconclusive and, moreover, that the
prevailing social and political climate was highly favorable toward
industry. By the 19th century, when Britain had established its reputa-
tion as “the workshop of the world,” copper smoke, along with
other industrial pollutants, was regarded at worst as a necessary and
localized evil. With Britain’s growing prosperity and international
importance based on its early lead in industrialization, such a stoical
attitude toward industrial pollution is hardly surprising. It is, how-
ever, far removed from the growing concern over the social costs of
industrialization at a global level in the late 20th century. Even a
cursory comparison of the attitudes shown toward copper smoke
with contemporary concerns over industrial pollution indicates a no-
ticeable shift in opinion concerning the costs and benefits of indus-
trial activity.

Nevertheless, even in the 19th century smelters that were seen to
attempt to deal with copper smoke could enhance their public im-
age, and the firm that paid most attention to the problem was Vivian
and Sons. Aside from the economic incentives to recover by-prod-
ucts, their response was in line with the high political profile main-

94Ashby and Anderson (n. 87 above), p. 78; and BPP, Annual Report of the Proceedings
of the Alkali Inspectorate, 1912 16 (1913), p. 444.
tained by the Vivian family within the community. Given that copper smoke was very much a visible problem in south Wales, it is understandable that this firm should wish to be seen in the vanguard of attempts to overcome it. When Henry Hussey Vivian was elevated to the peerage as the first Lord Swansea in 1893, a eulogistic pamphlet even stated overoptimistically that one of his major achievements was to transform “poisonous copper smoke into a useful by-product” through the introduction of the Gerstenhöfer furnace—such was the importance attached to the issue.95

Contrary to popular opinion, the success of Vivian and Sons’ attempts to curb local pollution was limited. The Gerstenhöfer furnaces dealt inadequately with sulfur emissions, while the manufacture of sulfuric acid had its own serious atmospheric pollution problems. Also, just as the highly toxic water used to treat copper smoke at the Hafod works in the 1820s was drained off into nearby waterways, liquids containing impurities such as arsenic, produced in the manufacture of sulfuric acid by Vivian and Sons using the Gerstenhöfer furnaces, were poured directly into the River Tawe, which became heavily polluted. In the words of Edward Ballard, of the Medical Department of the Local Government Board, so-called solutions to the copper smoke problem frequently led to the “substitution of one nuisance for another.”96

Copper smoke disappeared in Britain not because of the success of responses to the problem, technological or otherwise, but because of the changing structure of the copper industry and its eventual decline. First, the collapse of the Cornish mining industry in the 1860s and 1870s deprived smelters of an accustomed supply of ore of a particularly high sulfur content. At the same time, there was a growing tendency for copper ore to be exported to Britain in the form of regulus or roasted pyrites from which much of the sulfur had already been removed, thereby “exporting” the copper smoke problem out of Britain.97

97For instance, at the Rio Tinto Company mines in southern Spain, an Anti-Smoke League was formed by local farmers, the company faced “smoke riots” in 1888 in which thirteen people were killed, compensation had to be paid to more than sixteen hundred people, the government banned the use of certain processes, and the company was forced into a campaign to change the legislation which involved publishing propaganda pamphlets and bribing journalists and government advis-
Atmospheric Pollution and the British Copper Industry

By World War I, copper smelting in Britain was declining rapidly; by the early 1920s it had ceased almost entirely. With the demise of smelting, the copper smoke problem disappeared. In its place, the Swansea region suffered greatly from the expansion of the zinc, tin-plate, and other metallurgical industries. It was only with the closure of the last zinc smelting works in 1974 that the region was finally rid of smelter smoke, and only through the efforts of the Lower Swansea Valley Project that "one of the most concentrated areas of industrial dereliction in the British Isles" was finally rehabilitated.

---