Chapter 5. Lead, the old ways, and how science could help

The "new movement"

Chapter 4 mentioned the 1896 appointment of Adelaide Anderson as head of the recently-established team of Lady Inspectors of Factories. Her own book, *Women in the Factory* (1922)[1] and Anne Spurgeon's biography[2] describe the heroic fight by Adelaide and her colleagues, male and female. She recognised that she was in a time of great change in the battle for a healthy work environment. The 1891 Factories Act brought in a system of "special rules" for injurious processes, and in 1895 it became a requirement that medical practitioners notify diseases due to certain agents such as lead and arsenic. Adelaide wrote of a "new movement for applying scientific knowledge". In 1898, an energetic Medical Chief Inspector, Dr Thomas Legge, was appointed, and in 1899 an Engineering Adviser. The first exposure limits were propagated, and on the horizon was the possibility of making other measurements in workplace air, and in due course of quantifying risk. "And so – at last" wrote Adelaide " – we reached the possibility of obtaining effectual measures of control. The number of cases of poisoning began to fall…"[3] To show how this worked, we will leave the roughly chronological sequence of previous chapters, and in the next three chapters look at two case studies; first, the terrible tale of lead poisoning.

What should be done about lead?

In 1897, Adelaide reported two cases from a survey of married women with lead poisoning in the pottery industry, which illustrated part of the problem. A.B. in her seven years of marriage had had three miscarriages, five stillbirths, and one child born alive who had died in convulsions when a few weeks old; C.D., married seven years, had had four miscarriages, three stillbirths, and one living child, born when she was absent from work. A later report mentioned a third case, married fifteen years, nine miscarriages and one child living but sick.[4] These were far from isolated cases, and, as we shall see, their exposures were not necessarily the worst. Chapter 4 mentioned the inquest of a young girl whose job was to apply poisonous colours.

The terrible effects of lead had been known from ancient times, and industrialisation multiplied the number of cases. Ramazzini in 1700 mentioned white and red lead as hazards for painters; and described how potters who use lead paint and glaze suffer pallor, colic, fatigue, tooth loss, and neurological symptoms including palsy and paralysis.[5] Charles Thackrah, the Town Surgeon of Leeds, whom we met in earlier chapters, graphically described in his 1832 book the same symptoms, culminating in paralysis and death.[6]

White lead and women's employment

White lead, which both Ramazzini and Thackrah mentioned, had been very widely used as a pigment for centuries. It is basic lead carbonate, $PbCO_3$. $Pb(OH)_2$, and was manufactured by filling a tall room with successive layers of small pots of dilute acetic acid and strips of lead over a deep layer of spent tanning bark, and then closing the room for some weeks. The bark fermented and produced heat, moisture and carbon dioxide. The acetic acid vapour produced covered the lead strips with lead acetate, and moisture and carbon dioxide then produced layers of white lead (see Fig 5.1, from RH Sherard, *The White Slaves of England*[7]). The room was opened, and the strips of lead removed and scraped and rolled to detach the white lead, which was then ground, dried, and packed in barrels. Every step could give high exposure, but many of the women who knew the risk could not get other jobs. The white lead could be made into paint in the factory, or the painters themselves might do the mixing. Robert Tressell, who had himself been a housepainter, described this as one of the worst jobs for an apprentice, in *The Ragged-Trousered Philanthropists.*[8]

"This stuff came in wooden barrels containing two hundredweight and he used to have to dig it out of these barrels with a trowel and put it into a metal tank, where it was kept covered with water and the empty barrels were returned to the makers. When he was doing this work he usually managed to get himself smeared all over with the white lead…"

Fig. 5.1. Harold Piffard's picture of "A corner of a white lead factory". Public domain

Public and press concern led to the Factories (Prevention of Lead Poisoning) Act (1883), which laid down specific precautions, including watering of the lead strips before they were scraped and rolled. There were many more poisonings amongst women than men, but was this because more women were employed in the dirtiest processes? The numerous miscarriages and still-births clearly showed that unborn children were at risk. Moves to exclude women from the work were resisted by several groups: (1) some legislators who believed that adults should be able to take care of themselves; (2) women's advocates who insisted that women should be treated in the same way as men; (3) women needing work who could find no other employment; and (4) manufacturers who claimed that removal of the cheap female labour would raise costs and drive the industry overseas, where standards were allegedly lower. An account of the struggles is given by Anne Spurgeon in her biography of Adelaide Anderson.[9]

A problem was that it was only from 1895 that medical practitioners were required to report poisoning from lead or other specified substances. There had been earlier indications of the scale of the lead problem, from those responsible for workhouses, who made representations about the number of people disabled by lead poisoning who had to seek relief and admission.[10] Then from 1895 there were formal annual statistics, although some under-reporting was inevitable.[11] In 1900 there were 1058 cases and 38 deaths reported, of which 377 (6 deaths) were in white and red lead works, and 210 (8 deaths) in potteries.[12] Poisonings of painters did not have to be reported, as the majority of painters were not covered by the Factories Acts; and if they were reported inspectors had no powers to seek improvement. Nevertheless, 100 cases of poisoning in painters were reported in 1899.

The first air measurements, and the first OEL

It was clear that the general requirements of the Factory Acts would not on their own deal with many of the poisonous substances in use and other dangerous conditions, so the 1891 Factory Act permitted the Chief Inspector to propose special rules to deal with the problems. Until 1901, employers could object to the proposed rules, which led to long delays. Specialist engineering inspectors were appointed at about the same time. Adelaide Anderson was in the front line, and in her book you can sense her relief at the growing "knowledge and vigour of regulation". In 1898 Thomas Legge was appointed a Medical Inspector, and G Elmhirst Duckering, an inspector who was a "skilled chemist", was released to work on risks from substances.[13] We know that an engineering inspector, CR Pendock, and one of the Lady Inspectors, Florence Lovibond, worked on local exhaust ventilation.[14]

Elmhirst Duckering devised new weaponry, two methods of measuring the concentration of a contaminant in the air. Fig 5.2 shows the one which he used to measure the lead evolved while tinning,[15] ie coating of metal articles with lead or tin or a mixture of the two. With this he measured in the laboratory the relative amounts of lead made airborne by different parts of the process, and then in the workroom the concentration in the air close to the worker during different processes. From the time spent by the worker at different processes he calculated what we would call the time-weighted exposure. The second piece of apparatus (Fig 5.3)[16] was intended for dust, for example sandpapering of lead paint, which was found to give lead exposures up to 100 mg/m^3, and work in potteries using lead glaze (athough it is not always clear which sampler he used for which processes).

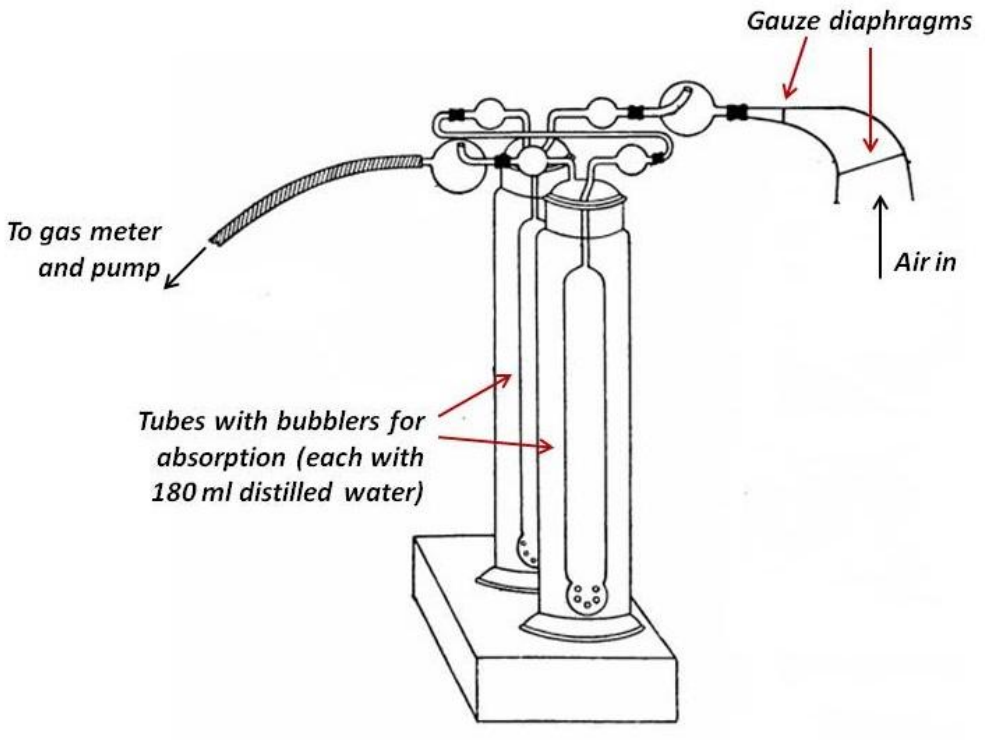

Fig 5.2. G Elmhirst Duckering's sampling apparatus used to investigate lead exposure in tinning. In workshop measurements, it was held in a retort stand so that the inlet (a metal funnel) was close to the worker's breathing zone. Glass wool could be packed between the two gauze diaphragms to collect particulate. The air then passed through two glass bubblers which Duckering said were very efficient at collecting other material. Aspiration was provided by a filter pump on a water tap, connected to the apparatus by a long rubber tube. Adapted from his paper in J. Hygiene, 8:474-503 (1908).

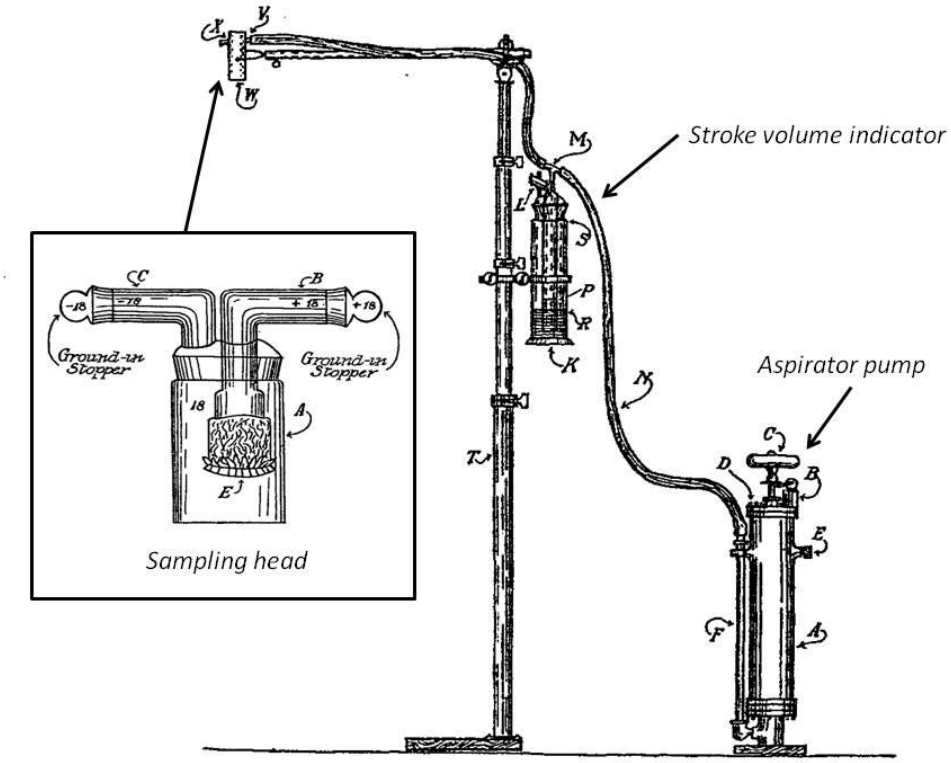

Fig. 5.3. Duckering's sampling equipment for dusts. The sampling head was about 6 cm high and contained a mass of wool used as a filter. This could be dried and weighed (or, if used for lead, analysed). The stand could be extended to about 2.7 m tall. The pump was worked by hand and the total volume collected was two or three hundred litres, which took about 20 min. Adapted from the 1910 Report of the Chief Factories Inspector. Public Domain.

Although Duckering's measurement methods were ground-breaking, in 1908 he proposed an idea which was if anything more revolutionary. The Special Rules for various trades spelt out detailed control methods, and this would continue for many years, but Duckering proposed that "The most scientific way of regulating a dusty trade would be to impose a limit on the amount of dust which may be allowed to contaminate the air breathed by the workpeople and to leave the manufacturer a completely free choice of methods by which this result may be obtained."[17] This is a very modern approach, although we now realise that the limits Duckering envisaged are not generally hard lines between safety and danger, and good control should be applied as well.

Duckering's idea was applied in 1912 by Thomas Legge, who collaborated with a senior pathologist, Sir Kenneth Goadby, in a book on "Lead Poisoning and Lead Absorption"[18]. In one of the chapters for which he was responsible, Legge pointed out that inspectors had powers to require ventilation and other actions if the contamination was "injurious to health" (and in fact had had them for over 40 years), but how much contamination was injurious? Legge knew the frequency of lead poisoning at different processes and the amount of time it took poisoning to appear, and he used these and Duckering's measurements to estimate that if the lead in air was less than 0.5 mg/m^3, "cases of encephalopathy and paralysis would never, and cases of colic very rarely, occur".[19] He says that the

lowest daily dose that would give chronic lead poisoning was about 2 mg, and in his PhD thesis Mark Piney has pointed out that if a worker inhales 10 m^3 in an 8-hr shift (a moderate exercise rate), this would correspond to a limit in air of 0.2 mg/m^3.[20] The exposure limit in Britain in 2021 is 0.15 mg/m^3, equal to the maximum allowed by an EU Directive.[21] Considering the crudity of Duckering's measurement methods, Legge was remarkably close.

Legge's proposal was probably the first occupational exposure limit in the English-speaking world. In 1898 regulations for cotton factories had imposed a limit of 900 ppm for carbon dioxide,[22] but this was as a measure of ventilation and not based on the toxicity of carbon dioxide.

Legge believed that 90% of lead exposure was by inhalation. Modern estimates of this percentage are much lower, perhaps because of better control of airborne releases, and modern control standards put more emphasis on blood lead levels as a measure of dose than airborne levels on their own. This will be discussed in the next chapter.

100 pages on control techniques – in 1912!

Legge's exposure limit is interesting because of its pioneering nature, but it is tucked away at the end of a section in the book, and Legge devotes much more space to details of control methods, giving credit to colleagues in the Inspectorate. Legge strongly prefers local exhaust ventilation (LEV) as more effective than respirators, but if a respirator is used it must ensure "first, that the air breathed is freed from dust, and secondly, that it should not incommode the wearer". Cotton protective clothing can accumulate dust and then act as a source, but light and ventilated protective clothing should be used where there is a splash risk. On LEV, Legge discusses air hood and duct design, problems of balancing different inlets to the duct, and the advantages of centrifugal over propeller fans. Maintenance of LEV systems requires "meticulous attention to detail". He criticises cyclones as ineffective for fine dusts, and prefers bag filters. He mentions a system suggested by CR Pendock of separating the dusty process from a human operator and operating it under negative pressure.[23] If electric power is available vacuum cleaners should be used for cleaning, instead of the "barbarous methods" of sweeping or blowing. Floors and walls should be impervious. Processes should be designed to minimise contact and contamination. Workers should be trained in good practice. After 40 pages on general principles of control, Legge spends 60 pages applying them to particular processes.

Despite the changes in technology since, this all has a very modern feel, and it is hard to remember that Legge and Goadby's 1912 book is closer in time to Charles Thackrah (see chapter 4) than to us today. Legge also takes for granted that the employer should provide a safe environment, without relying on personal protective equipment, whereas in the 1890s even some inspectors took the attitude that although women and children might need protection, it was the responsibility of adult male employees to look after themselves.[24] Adelaide Anderson, who was a witness and participant in all these changes, summarised them: "the work that was waiting, almost untouched, in the last decade of the nineteenth century, to be overtaken by persistent, meticulous application of this science to protection of the health of the industrial worker"[25]

But there was one more step available. Could we completely get rid of lead in many of its uses that were difficult to control? For the controversy this question raised, we must wait for chapter 6.

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[1] Adelaide M Anderson, *Women in the Factory: An Administrative Adventure 1893-1921.* London, John Murray, 1922. (London, Forgotten Books, 2015, ISBN 978-1-332-21304-7)

[2] Anne Spurgeon, *Women and Children in the Factory. A Life of Adelaide Anderson (1863-1936).* Malvern, Aspect Design, 2016.

[3] Adelaide M Anderson, *Women in the Factory: An Administrative Adventure 1893-1921.* London, John Murray, 1922. (London, Forgotten Books, 2015, ISBN 978-1-332-21304-7) pp 95,101.

[4] Quoted from the 1897 and 1901 Chief Inspector of Factories Annual Reports by Adelaide M Anderson, *Women in the Factory: An Administrative Adventure 1893-1921.* London, John Murray, 1922. (London, Forgotten Books, 2015, ISBN 978-1-332-21304-7)

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[9] Anne Spurgeon, *Women and Children in the Factory. A Life of Adelaide Anderson (1863-1936).* Malvern, Aspect Design, 2016

[10] Chief Inspector of Factories Annual Report for 1933, p45

[11] Chief Inspector of Factories Annual Report for 1933, p 50.

[12] Chief Inspector of Factories Annual Report for 1933, p 52

[13] Adelaide M Anderson, *Women in the Factory: An Administrative Adventure 1893-1921.* London, John Murray, 1922. (London, Forgotten Books, 2015, ISBN 978-1-332-21304-7) pp 97, 100.

[14] Legge TM amd Goadby KW, *Lead Poisoning and Lead Absorption.* London, Edward Arnold, 1912. Pp 219 & 277. https://ia600209.us.archive.org/35/items/cu31924003449752/cu31924003449752.pdf

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[16] Chief Inspector of Factories, Annual Report for 1910, pp202-203.

[17] G Elmhirst Duckering, *Report on an Investigation of the air of work-places in potteries*. In: *Report of the Departmental Committee appointed to enquire into the dangers attendant on the use of lead and the danger of injury to health arising from dust and other causes in the manufacture of earthenware and china and in the processes incidental thereto, including the making of lithographic transfers.* Volume 2, Cd 5219, London: HMSO. Quoted by Mark Piney, *OELs and the effective control of exposure to substances hazardous to health in the UK*, HSE, 2001 http://www.hse.gov.uk/coshh/oel.pdf

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[25] Adelaide M Anderson, *Women in the Factory: An Administrative Adventure 1893-1921.* London, John Murray, 1922. (London, Forgotten Books, 2015, ISBN 978-1-332-21304-7) p102.