Lead poisoning and intelligence: a search for cause and effect in the Scottish Mental Surveys

In 1932 and again in 1947, the Scottish Council for Research in Education (SCRE), at the urging of the Population Investigation Committee and the Eugenics Society, undertook the Scottish Mental Surveys (SCRE, 1953, p. 1). Testing two cohorts, one of 87,498 children in 1932 and another of 70,805 children in 1947 (SCRE, 1949, p. 5), researchers set out to measure - using the same validated test each time - the intelligence of every Scottish child 11 years of age (see notes 1 & 5). The stated impetus for the Surveys was a fear that average Scottish intelligence was declining, perhaps due to a tendency for the more intelligent members of society to produce fewer progeny then those who were less intelligent (Maxwell, 1961, p.10). But when investigators compared the results of the 1947 Survey with those from 1932 their predictions were completely upended. Instead of average intelligence declining, as was feared, it had risen, substantially (SCRE, 1949, p viii).

The Surveys were unparalleled - two surveys of entire populations, not just samples. Nothing like them has occurred before or since. And the contexts in which they took place are of interest. Scotland's resources were severely stretched in both 1932 and 1947. In 1932 the country was feeling the effects of the Great Depression, and in 1947 it was both grieving and rebuilding following the devastation of World War II. Despite those obstacles, the country's leading educators felt compelled to conduct two massive research studies in an era before modern computers. Each test was scored and tabulated by hand. It is hard to imagine the concern and worry over Scotland's future that must have existed to justify such undertakings.

With the 1947 results in hand, investigators began to look at cause and effect. There was a belief that genetic evolution had not played a role, the 15 years between Surveys being too short a period for such change to have taken place (Maxwell, 1961, p. 10). Beyond that, however, there has been no agreement to date on cause. Although researchers felt that environmental influences had undoubtedly played a role (SCRE, 1953, p. 50), in a retrospective, Ian Deary and co-authors labeled the 1947 results as an early example of the "secular rise in intelligence test scores" due to the "Flynn effect" (Deary, et al., 2009, p. 24). The Effect describes what happens when the same intelligence test is administered repeatedly to successive generations of test takers. Regardless of test design the current generation invariably scores better on the test than did previous generations (Flynn, 1999). Flynn's explanation for the Effect is that intelligence increases in response to an increasingly complex world (Flynn, 2013) .

If children in 1947 were more intelligent than those in 1932 because of the Flynn effect, then the story ends and the Scottish Surveys return to obscurity. But there is another explanation, one that addresses the rise in test scores without invoking Flynn's theory. That explanation holds that in 1932 a large number of surveyed children suffered from chronic lead poisoning and that this caused test scores to be abnormally low. As environmental lead levels fell, and children absorbed less of the metal, intelligence rose to the level recorded in the 1947 results. Was chronic lead poisoning widely prevalent in Scotland in the first half of the last century, and were the Surveys bellwethers of the human cost of that event? The evidence will show that, at home and at work, lead had laid siege to Scotland, and only gradually beginning in the 1920s did the threat diminish. Of all the perils from lead, the most pervasive was the presence of the metal in drinking water, not at its origin but as a byproduct of its delivery to the consumer.

"*Roughly 150 years ago, cities all over the world installed lead pipes to distribute water*." wrote Dr. Werner Troesken in his book *The Great Lead Water Pipe Disaster* (Troesken, 2006, p. 9). Municipally owned lead service pipes for the delivery of drinking water existed in Scotland until well into the early part of this century (Government of Scotland, 2002). In the mid-1970s, in response to growing concerns about lead in the environment, authorities conducted the most comprehensive survey of lead in water ever undertaken in Great Britain (Central Unit on Environmental Pollution, 1977, p. iii). What they found was that the amount of lead in drinking water correlated directly with the lead content of the pipes and fixtures supplying the water (Central Unit, p. 10). As part of the survey, authorities drew water samples from 2,317 randomly selected households in England, 574 in Scotland, and 290 in Wales (Central Unit, p. 6). After confirming that the survey's demographics matched those of the countries under study, investigators extrapolated their findings. Based on "first draw" samples (see note 6) they estimated that 44.6% of homes in England, 58% in Scotland, and 37.8% in Wales had lead levels above a detectable minimum (Central Unit, p. 7). For the highest detected levels of lead (0.3mg/L and greater), there was an even greater difference; 0.6% of homes in England, 11% in Scotland, and 0.8% in Wales were estimated to have such levels. For "daytime" samples (see note 7) the differences trended in the same direction albeit with different numbers (Central Unit, p. 8). Lead-solvency, here defined as any process able to release lead into drinking water whether corrosion is present or not, explained much of the difference.

In the presence of lead plumbing the amount of lead in drinking water may be increased by: a) increase in water acidity, b) increase in water temperature, c) age of the plumbing, d) the use of lead-lined residential storage tanks, e) the use of pipes made of different metals (usually copper and lead), f) contact time between lead and water, g) water pressure and turbulence of flow and, h) thermal expansion of the pipe (Britton, 1981, p. 350). It can also be increased through the disruption of pipe deposits from public water flow cycling on and off (White, p. 461) and, as described above, the total lead content of the pipes and fixtures that connect the water main - which was usually made of steel or iron, not lead -

with the household taps (Herring-Shaw, 1909, p. 90). In Scotland acidic water was the major reason for lead-solvency.

Published studies on lead contamination of municipal water supplies have singled out Glasgow over Edinburgh despite the fact that the water systems of both cities drew from surface sources in areas with decidedly acid soil chemistries. However, given that Glasgow was more than twice the size of Edinburgh in the early part of the Twentieth Century, and drew water from an area where the soil chemistry was slightly more acidic (The Scottish Water Advisory Committee, 1963, pp. 6,7), the emphasis on Glasgow is understandable. Reports have focused on the consequences of ingesting lead-solvent water. But in truth the water contaminated everything it touched. In the short term such contamination was trivial, but over months and years objects on which water was allowed to dry - clothing, floors, table tops, pots and pans, kitchen counters, dishes, etc. - ran the risk of accumulating lead. Together with other sources of lead in the environment it all added up.

Reliable "always flowing" public water systems were uncommon in Great Britain until well into the Twentieth Century. For a variety of reasons, water service was routinely interrupted for several hours each day forcing the householder to look for other ways to keep water available at the tap (Hellyer, 1898, p. 251) (Raynes, 1920, p. 254). The usual solution was the household "cistern", a large tank integrated into the plumbing that held as much as several hundred gallons or more. Frequently this was a large box made either of wood lined with lead or wholly of lead (Hellyer, p. 251ff). Cisterns were also common in rural areas where household water needs were met solely through the collection and storage of rain (Raynes, p. 255). When persistent published reports appeared alerting readers to the risk of poisoning from lead cisterns, scattered efforts to eliminate the cistern as a source of drinking water began. Shortly after the turn of the century, for example, one municipal plumbing code mandated that water from the "drinking" tap (usually the kitchen) had to be plumbed directly from the public water main bypassing the cistern completely (Herring-Shaw, p. 138). Sometime before 1940 this would become standard recommended practice (Building Research Board, 1944, p. 10) (Frazer, 1940, p. 108). As another example, a second cistern constructed of lead-free material was sometimes installed as a source of potable water in areas where the public water supply was routinely interrupted (Society for the Sanitary Inspection and Construction of Houses, 1881, p. 932). Finally, where public water systems were charged and under pressure at all times, providing an uninterrupted supply, the cistern risked becoming superfluous. But improvements to plumbing infrastructure were not quickly or widely adopted. When they began to be implemented as part of new housing construction, it was too little and too late for the 1932 cohort, all of whom had been born in 1921; 87,438 children whose most vulnerable growing-up years would occur during the 1920s.

Although there had long been a recommendation to construct cisterns and pipes of lead-free materials in lead-solvent areas (Hart, 1904, p. 187), there was a countervailing belief that given the right water chemistry further dissolution and corrosion of plumbing would be prevented once the action of water on lead had laid down a protective and impermeable barrier of metallic salts, which combined with organic matter in the water would shield the soft bare metal from further damage (Hart, p. 188; Raynes, p. 253; White, p. 461). The problem would correct itself in effect. However the barrier itself could become damaged for any number of reasons, exposing the consumer to lead once again. A second obstacle to the adoption of plumbing improvements was that lead plumbing, particularly lead cisterns, were practically indestructible, as one observer noted, leading to extraordinary long replacement cycles. In an investigation of a spontaneous outbreak of lead poisoning in the Scottish Highlands in 1974, the source of the lead was found to be the plumbing and in particular the lead cistern, which in one case was almost 200 years old (Goldberg, 1974). Finally, in the first half of the Twentieth Century the vast majority of Scotlanders did not own the homes they lived in. They rented. It is estimated that in 1914 this circumstance applied to 90% or more of the population of Scotland (Abrams & Brown, 2010, p. 48; Niven, 1979, p. 25). That astounding statistic meant that the average householder did not have the legal right to remove lead from the plumbing even if he or she wanted to, and in the absence of government mandates or financial penalties, the landlord had no incentive. Improvements would have to wait for government action on housing as well as official recognition that lead poisoning from drinking water was a problem.

Although Glasgow, Scotland's largest city in the early Twentieth Century, had some of the worst slums in Europe, housing blight had not spared the rest of the country. In an official report published in 1917 on the housing problem attendant to the working classes, investigators concluded that 236,000 new houses needed to be constructed throughout the country both to replace houses unfit for habitation and to raise overall living standards to an acceptable level (Royal Commission on Housing in Scotland, 1917, p. 347). As a result of the Commission's findings, two government initiatives were launched, one in 1919 and one in 1924 (Niven, pp. 26-27). From published statistics it can be estimated that 10% of the 236,000 had been constructed by the end of 1923, 17% by 1925, 32% by 1927, and 41% by 1928. Although the initiatives languished and finally ended with the economic collapse of 1929, new government programs in 1930 and 1935, as well as the return of speculative building following a 24 year hiatus, resulted in a building boom in Scotland from 1930 to 1939 (Niven, pp. 29-30). As a result, 64% of the 236,000 houses were completed by the end of 1931 and 108% by the end of 1935 (Ministry of Labour, 1927 (v. 35), 1928 (v.36); Department of Health for Scotland, 1927-1936). The new houses, fitted with plumbing that offered lower levels of lead contamination of water, would fully benefit children in the 1947 cohort but only a small number of those in the 1932 cohort.

As households were moved out of old quarters and into new, trading old lead plumbing for new in the process, the risk of lead poisoning from drinking water dropped fractionally. Although this was particularly true where drinking water was not supplied from a lead cistern in the new house, simply trading old lead pipes for new lessened the risk of lead-solvency at least for a time. A review of published sources suggests that over the life span of a lead water pipe, which was said to average 50+ years (Britton, p. 354), lead-solvency progressed through three stages: 1) the "conditioning" stage - in this stage lead-solvency began high and then gradually diminished as a protective barrier was laid down on the interior surface of the pipe. This stage was present whenever new or repaired lead pipe was placed into service. 2) the "conditioned pipe" stage - in this stage lead-solvency and corrosion were at their lowest. The length of this stage was determined by the adherence and permeability of the protective barrier. 3) the "aged lead plumbing" stage - in this stage both corrosion and lead-solvency increased as a result of failure of the protective barrier. "Aged lead plumbing" was found to be a reliable predictor of lead-solvency (Britton, p. 354; Richards, 1980, p. 323). The importance of the stages within the context of the Surveys is that, during the children's most formative years, a greater number in the earlier cohort grew up with plumbing in stage 3, whereas in the 1947 cohort a greater number grew up with plumbing in stages 1 and 2.

How often builders failed to include a lead cistern in new construction is not known. But plumbing trade books of the period advised against supplying water for drinking and cooking from lead cisterns particularly in areas where the water was lead-solvent, a condition that applied to most of Scotland (Raynes, p. 286; Herring-Shaw, p. 113; Hart, p. 187). In addition, British medical publications, some from before the turn of the century, roundly condemned the practice of using lead cisterns as a source of drinking water (White, 1889; Goldberg, 1974; Swann, 1892). More recent information on the use of lead cisterns in Scotland was published as part of a follow-up investigation of the Edinburgh Lead Study, a survey of 500 children living in central Edinburgh in the 1980s (Raab, et al., 1993). At the time it was estimated that there were between 30,000 and 60,000 lead-lined water storage tanks still in use "for all domestic purposes" mainly in the Edinburgh and Glasgow areas (Britton, p. 358). In the follow-up study investigators examined the cold water supply in 480 of the children's homes. Non-public housing that was rented as opposed to owner occupied was more than twice as likely to have cold water supplied from a lead storage tank. The difference between public housing and privately rented homes was even more stark, the latter being 10 times more likely than the former to have cold water supplied from a lead tank. The study also found that more recently built homes were far less likely to include such tanks then were houses built during the late Victorian period or early Twentieth Century (Raab, et al., p. 197). In 1931, in an obscure reference, came a hint that municipal authorities were ready to acknowledge that lead-solvency was a problem (British Waterworks Association, 1931, p. 17). And in 1938, 2 years after the birth of the 1947 cohort, lead-solvency made an appearance before the law. As reported In a lecture on water and public health before the Royal Institute of Chemistry of Great Britain and Ireland, the speaker stated that a judge had ruled that water companies had a duty to either warn customers of the danger of lead-solvency or take steps to mitigate it (Carey, 1946, p. 21).

But for children participating in the Scottish Surveys drinking poisoned water wasn't the only lead peril they faced. Lead from occupational exposure was another. Spanning the width of Scotland from the Firth of Forth on the east coast to the Firth of Clyde on the west lay the heart of the country's industrial might for much of the Nineteenth and early Twentieth Centuries. And at the center of that lay the largest shipbuilding industry the world had ever known. Along the banks of the river Clyde and its estuary, where most of the ships were built, as well as at Leith, Rosyth, and Burntisland on the Firth of Forth, lay a score or more of shipbuilding, shipbreaking, and ship repair facilities (Moss & Hume, 1977, p. end plates). Shipbuilding was dirty, dangerous work (McKinlay & Hampton, 1991, p. 21). And often hidden in the dirt was dust and residue from lead. Lead was widely used in shipbuilding. It could be found in paint and plumbing (as pipe, conduit, and solder), as a lubricant, in engine parts, as corrosion control coatings on plate steel, and as sheet lead for floors and bulkheads in areas subject to condensation such as galleys and room-sized refrigerators, (Consolidated Mining and Smelting Co. of Canada (C.M.& S.Co.), 1944, p. 255). After peaking in 1920 shipbuilding in Scotland went into decline and never fully recovered. Although the industry rebounded somewhat in the late '30s, gains in worker productivity as well as a migration of skilled labor away from the industry during its lean years reduced the insured work force from 97,000 in 1921 to 41,000 in 1936 (Ministry of Labour, 1921, 1936; Jones, p. 112; see note 3). That meant that far fewer wage earners were potentially bringing home lead contaminated clothing to families that could count as members children in the 1947 cohort, roughly 80% of whom had working class parents (SCRE, 1953, p. 215; see note 2).

By 1920 what promised to be difficult years ahead for the Industry became even more so with the withdrawal of the British Admiralty from the business of building ships, a move required by international treaty (Peebles, p. 5; Campbell, p. 134). Since many commercial contracts ended up generating losses for the shipyards - the result of competition, technical challenges, overcapacity, labor unrest, supply chain problems, and the vicissitudes of world trade - the withdrawal removed the only reliable funding source the industry had known (Slaven, 1977, p. 202; Peebles, 1987, p. 141). It also removed a role model for lead safety at a critical time.

"*The Admiralty have for some time recognized the dangers attaching to the use of lead paints, and have taken precautions accordingly*". That statement, given in testimony before a committee investigating the dangers of lead paint, revealed how seriously the British Navy took the threat of lead poisoning among ship's painters. The point was driven home by the fact that the Navy had become a leader in the use of lead-free paints on the interior surfaces of ships (Committee on Lead Paint, 1915, p. 59). A man painting ships for the Navy could expect to benefit from the following, all provided at Admiralty expense: plenty of soap, nail brushes, hot water and towels and the time to use them before lunch and at shift's end; enforcement of the preceding by an overseer stationed at the door of the washroom ("no wash-up" meant "no wages"); work overalls and their regular washing at a commercial laundry (a benefit usually denied those working on civilian ships (Committee, p. 38; Reid, 2010, p. 102) and, regular examinations for signs of poisoning (Committee, p. 75). Although the speaker was referring to activity at Government owned dockyards, it is illogical to believe that the Admiralty would abandon this or any regulation simply because a naval vessel was being built, refitted, or repaired at a commercial rather than at a navy yard. And while it may be comforting to believe that the Admiralty instituted the work rule out of a sense of humanity, the truth is probably more prosaic. Painters getting sick on the job and having to be replaced could delay the launch of a badly needed ship.

When a commercial yard enjoyed business from the Admiralty, yard workers built merchant ships and navy vessels side by side (Peebles, p. 3). Admiralty contracts contributed more than five times that of merchant contracts to yard overhead and profit at two of the leading Clyde shipyards in the years leading up to both Wars (Peebles, pp. 145, 147). That kind of financial security would have made the Admiralty the most important customer for any yard lucky enough to have the Navy's business. So it is difficult to imagine a scene where ship's painters are up to their elbows in soapy water before mealtime at a berth where a navy vessel is being built, while at an adjacent berth in the same yard workers painting a merchant ship are sitting down to eat with paint encrusted hands. Although that may have occurred, a more optimistic view is that the Admiralty's position on lead safety would have been embraced by yard management. Coincidental with the departure of the Admiralty from shipbuilding, spray painting began in shipyards. The hazards associated with spraying lead paint in confined spaces were well known, and for that reason spray painting in a ship's interior was strongly resisted by labor unions (Reid, p. 101). In better times, in a crowded yard, with berths occupied cheek by jowl and workers swarming over every ship, even exterior spraying could be a hazard as a mist of lead paint would drift from ship to ship. But as the shipbuilding industry fell into disarray from 1920 onward prompting yard management to cut costs, the painters, never well organized to begin with, lost ground. An example was the demise of an agreement reached at the end of the War between the union and yard management for the latter to provide clean overalls on a regular basis. That benefit would disappear sometime before 1930 (Reid, p. 102). As World War II approached and commercial shipyards revived, painters regained much if not all of their lost ground, in step with the return of the Admiralty to shipbuilding.

The blow to safety that followed the Navy's exit from shipbuilding was compounded by a simultaneous surge in shipbreaking at the end of the War, a result of obsolete naval vessels being scrapped (Jones, p. 95). Carried on at 70 different locations throughout Great Britain (Hoffman, 1933, p. 29), shipbreaking was the dirtiest most hazardous work that a shipyard could engage in. Acetylene torches cutting through plate steel covered with lead, cadmium, zinc, or nickel chromium either as paint or corrosion coating, sending up great plumes of toxic gases laced with heavy metals. In 1924 the number of cases of lead poisoning reported among workers in the shipbreaking industry was higher than 15 other lead-related occupations and industries, and 30% higher than the next highest number

(Hoffman, 1927, p. 11). Old photos of the era show shipyard workers laboring in what appears to be street clothes, a conclusion supported by oral histories (McKinlay & Hampton, pp. 22,23). Pictures show vests, jackets, coats, trousers, and cloth caps being worn, occasionally supplemented by overalls especially if painting, welding, or lead burning was part of the job. But unless the work was for the Admiralty, all the clothing including the overalls came home to be washed (see note 8).

Apart from crowded tenements built with the working classes in mind, much of the housing for industrial workers in the urban centers of Scotland in the first quarter of the Twentieth Century began life as middle and upper class homes, many built during the late Victorian era, or as failed real estate developments for the middle class (Niven, p. 20). As the affluent moved away from the city's center with its crowding and pollution, or emigrated, their now empty houses were transformed into rented quarters for working class families, "made-down housing" in the local vernacular (Allan, 1965, p. 599; Cairncross,1954, p. 194; Fraser & Maver, 1996, p. 369). A single house, remodeled and subdivided into flats, would become home to several families, some living in a single room that functioned as kitchen, sleeping quarters, and living area with one privy for the entire building. Many of these quarters consisted of no more than two rooms regardless of the number of occupants (Begg, 1987, p. 7). Although the "made-down" properties would rapidly deteriorate In the 1920s from lack of maintenance (Horsey, p. 13), an epidemic of lead poisoning from children eating old lead paint would not materialize (BMJ, 1955) as it had in Baltimore in the 1940s and '50s. Lead paint was not widely used in Scotland for domestic purposes (Committee on Lead Paint, p. 31) perhaps because of the expense.

The other source of occupational lead during this period was the munitions industry which in Great Britain as elsewhere employed large numbers of women during the War. By one estimate tens of thousands of women in the West of Scotland alone were employed at the height of production, and by all estimates at least that number and probably many thousands more were engaged throughout Scotland (Baillie, 2002, p. 34; Scott & Cunnison, 1924, p. 98; see note 4). In addition to the ever present risk of fire, explosion, and occupational illness, munitions manufacturing was hazardous due to the large number of people working in close proximity to dangerous machinery. The hazards were made worse by the fact that many workers and managers, inexperienced and hired in a frenzy after munitions production was found to have fallen far short of need (Baillie, p. 1), were unfamiliar not only with munitions manufacturing but with heavy industry of any kind. Women who up until then had seldom set foot outside the home could find themselves after a short training course working long hours including nights and Sundays, man-handling 80 pound artillery shells across a crowded, noisy, factory floor close to fellow workers each intent on coaxing the machine in front of them into milling a piece of smoking hot metal to exact specifications. In the major urban centers of Scotland, munitions manufacturing focused mainly on heavy shell and bombs rather than small arms ammunition (Baillie, p. 28). In view of the urgency of the situation at the Front every available resource was pressed into service. Local garages, bicycle repair shops, even a golf equipment manufacturer became entrepreneurial centers of munitions production (Baillie, p. 29; Scott & Cunnison, p. 94). There was an acknowledged lead hazard in such work. Lead paint was used to protect finished munitions from corrosion, alloyed with steel to make the latter easier to machine (C.M.&S.Co.; p. 237) as an essential component of artillery Shrapnel shells, in soldering and tinning processes, and to harden and temper steel used in making bombs and shells. As part of the hardening process, the steel was immersed in a bath of molten lead to bring the former to a uniform temperature (Hamilton, 1915, p. 64; Ministry of Munitions, 1917, p. 100). Evidence has shown that any time an object is immersed in a lead bath, the thin layer of lead oxide floating on the surface of the molten lead breaks into pieces, some microscopic in size. The smallest of the pieces may become airborne floating as invisible particles (APHA, 1942, p. 7). What precautions were taken to prevent these particles from being inhaled, or whether authorities were even aware of the problem, is unknown. However by War's end 12,000,000 artillery shells had been produced in Scotland alone (Baillie, p. 22). Every one of these shells was heat treated either by immersing it in molten lead or by other means (Hamilton, p. 59).

Although the Ministry of Munitions' Committee on the Health of Munition Workers issued comprehensive safety guidelines intended for the protection of workers (Ministry of Munitions, 1917), serious questions have been raised as to how closely these guidelines were followed in light of the relaxation of labor laws governing the conditions of industrial employment for the duration of the War (Baillie, p. 186). Given lax enforcement it would be difficult to believe that there were not more than a few women who emerged from the experience having absorbed lead at their place of work, a claim for which there is some evidence. Sometime after the signing of the Armistice in 1918, the Ministry of Munitions' Committee on the Health of the Munition Workers issued its final report. Included in the report was a section written by a senior medical officer who had examined 1,156 women at eight munitions factories throughout Great Britain (although none in Scotland). The examiner observed that in addition to other findings, up to 26% of women complained of constipation; up to 32% had several carious teeth; as many as 37% had complained of indigestion, abdominal pain, or loss of appetite; up to 30% of nervousness, irritability, depression, or difficulty sleeping; as many as 59% of recurrent headaches; and as many as 28% of muscular aches and pains. Each complaint was noted at all eight factories although the frequency of each varied considerably from factory to factory (Health of Munition Workers Committee, 1918, p. 141). This suggests that the complaints were work related and not something that the women brought from home. All of the findings have been associated with proven cases of chronic lead poisoning. And while no single finding is specific for lead poisoning (each can be seen in other conditions), the fact that all of the findings were observed over a single time period, in a group of women all doing related work and all with known occupational exposure to lead, makes it highly likely that lead was causative. A number of these very same women would go on to give birth two or three years later to children who would participate in the 1932 cohort. That mothers can unknowingly poison their unborn child with lead even years after maternal lead exposure has ended is well documented (Rastogi & et.al., 2007; Silbergeld, 1991).

In 1927 came the opening that would allow information on the dangers of lead to reach a wider audience. Issued in December of 1926 to go into effect January 1 of the following year, the Lead Paint (Protection Against Poisoning) Act made mandatory a host of new requirements for firms that used lead paint to paint buildings (MacKenzie, 1926). In addition, all painting contractors whether they used lead paint to paint buildings or not, had new reporting requirements that would allow health officials to track the whereabouts and work activities of all employed commercial painters. (Ministry of Labour, 1927, p. 13). The practical effect of the Act was to reduce the use of lead paint. "*The best that can be hoped",* wrote Dr. E.L. Collis of the Act," *is that employers, rather than be bothered with complying with the code, will adopt the use of paints which do not contain lead. There is already a considerable tendency in this direction"* (Collis, circa 1927). Because the Act would have added to the cost of painting, official language on the dangers of lead paint would likely have appeared in every painting contract, every deal negotiated with a customer, and would have been conveyed to every employee retained, hired, or released by a firm. In this manner public awareness of the dangers of lead had an opportunity to advance.

Results from the 1947 Survey raised several questions. Two of the more interesting dealt with the participation of girls in the study, and the distribution of test scores by educational regional authority respectively. Of the former James Maxwell wrote that "*The question must remain open, one major difficulty, the fact that most of* the *increased score in 1947 was due to the girls, has to be accounted for in any explanation*." (Maxwell, 1961, p. 10) A proposal now put forward is that girls absorbed more lead than boys because the former's household chores resulted in more lead exposure. In a working class home the wife and daughters did the heaviest housework; washing clothes, scrubbing floors (including, as a paying part-time job, scrubbing community staircases of which apparently there were many, in tenement buildings and in "made-down" housing), and cooking. Boys had some domestic responsibilities as well but more of their time was spent outside the house working at part-time jobs the most common of which was delivering milk (Lewis, p. 57; see note 9). Lead contaminated clothing piled in the corner of a crowded flat waiting to be washed was the responsibility of the mother and her daughters. In houses that were home to more than one industrial worker, a not uncommon occurrence, as many households sublet space in order to make ends meet (Royal Housing Commission, p. 100), the quantity of contaminated clothing could be doubled or even tripled. Since laundry facilities for working class families were always communal (Abrams & Brown, p. 61), this made lead-contaminated clothing a hazard for others as well. Lead poisoning in families from lead brought home from work as dust and residue had become such a problem in

Great Britain that sometime around 1911 premiums for workman's compensation insurance for painters were increased because of it (International Labour Office, 1927, p. 84). But as events conspired to reduce occupational lead exposure - an unexpected benefit of the pullback of the shipbuilding industry, the return of the Admiralty to commercial shipyards, and the Lead Paint Act of 1927 - the quantity of lead dust and residue in the home diminished, a clear benefit to children in the 1947 cohort. "*It is interesting to note*", wrote the authors of the 1947 results, "*that the superiority of the girls* [over the boys] *is most marked in the lower* [end of the range] *of score* [that is, the lowest 10% of scores] (SCRE, 1949, p. 91)..." Approximately 90% of these scores were claimed by children from working class families (SCRE, 1953, p. 113). If any improvement in test scores were to occur due to a reduction in occupational lead contamination of the home, it is in these scores that change would have been expected and was in fact seen.

The second question concerns the distribution of test scores by regional groups of educational authorities. A similar analysis was not completed for the 1932 Survey."*The general trend*", wrote James Maxwell "*is a decrease in average score from the South-East to the West and North* [of Scotland] *with Orkney and Zetland being exceptions"*. Orkney and Zetland (islands in the far north of the country) together contributed about 0.6% of children participating in the Survey. Maxwell continued, "*It is rather hazardous to attempt an explanation of these differences...*" (Maxwell, 1961, p. 54). An examination of topographical maps of Scotland reveal two phenomena that track the distribution of test scores remarkably well; the distributions of peatlands and soil acidity. Peatlands become more numerous as one moves from the South-East (where average scores were higher) to the North and West (where average scores were lower) (James Hutton Institute, 2017). Where there is more peat the soil is (on average) more acidic, the result of organic acids having been leached from the peat. For the same reason water drained from peatlands (a major source of drinking water in Scotland) is acidic. Since acidic water is lead-solvent and lead water pipes were present throughout Scotland at the time of the Surveys, it can be argued that lower intelligence test scores in the West and North of Scotland were the result of greater ingestion of lead from lead-solvent water in these regions.

Occupational lead poisoning, a reportable disease in Great Britain for most of the Twentieth Century (although not until 1927 for building and carriage painters), fell in uneven fashion from a peak of more than 400 cases in 1923 (including almost 50 deaths) to 168 cases (including 17 deaths) in 1935 (Hoffman, 1927, p. 10; Ministry of Labour, Sept 1936, p. 319). The decline occurred despite the fact that between 1931 and 1936 lead consumption increased by over 30% in Great Britain (C.M. & S. Co.; p. 71). From the late '30s into the early '40s the annual number of cases of occupational lead poisoning in Great Britain from all sources averaged around 115 with few if any deaths (Ministry of Labour Gazette, 1937-1941; vols. 45-50).

It is interesting to speculate on what might have happened had events occurred otherwise. If, for example, childhood lead exposure had stayed the same or perhaps even increased between the first and second Surveys. Would a higher level of lead exposure have reversed the outcome, with the 1947 cohort showing a lower intelligence than the 1932 cohort, confirming everyone's worst fears? Would such an outcome have strengthened the hand of the eugenicists, or perhaps that of the social reformers? A number of children (less than 1% of either cohort) continued to be studied for several years (Maxwell, 1969). Although differences in educational attainment and rates of marriage and fertility were recorded, none of these have shed light on the difference in intelligence between the cohorts. There is the feeling too, wrote Ian Deary, "*that the* [Scottish Mental Surveys] *were born of the concerns of a passing age*." (Deary, et al., p. 27), a veiled reference perhaps to the fact that intelligence did not decline as had been expected. It is obvious too from reading published reports that educated people of the period were not naïve about the dangers of lead. They feared it as much as people fear it today. And if their families had sufficient resources, they likely used them to build lead-free cisterns, install lead-free water pipes (if they were available) and avoid lead-related occupations. But lead also had economic importance. Early in the era water pipes might have to have been custom built, from scratch, on site, if there was to be an alternative to toting water from a well in a bucket. Lead was the only material that would allow a plumber to fashion a water pipe from a flat piece of metal. To question the use of lead in munitions, in shipbuilding or other heavy industry, or in plumbing, could have been viewed as unpatriotic in a country whose economy (and defense) critically depended on the metal. So even for the most wary and the best informed there was sometimes no alternative to lead. The SCRE investigators believed that the key to understanding the results of the 1947 Survey lay in understanding the family: its size, the child's position in the family, the intelligence of other family members, and the occupation of the father or guardian (Maxwell, 1961, pp. 9-11). With more than 50 years of perspective to work with, that understanding can perhaps be stated as follows. Families from the more affluent classes, living in better housing, exposed to no lead at work and little or none at home, and enjoying good nutrition, fared better. Families quartered in substandard housing, exposed to lead at home and at work, and living a subsistence existence, fared worse. Experience has taught that evidence of chronic lead poisoning in urban slums as well as in rural poverty can easily escape detection. In hindsight that certainly seems to be the message here.

Notes

1. Only children at school and in class the day of the Survey were counted. Children absent from school the day of the Survey (@ 4,500 children) are not included in the figures. No attempt was made to locate and test these children after the fact. It is not clear if the Surveys were announced in advance. If so then some families may have elected not to allow their children to participate

2. From a random sample of 10% of the children investigators in the 1947 Survey obtained information on family living conditions, father's occupation, the height and weight of the child, certain physical disabilities of the child, and other information. None of this information was obtained from children participating in the 1932 Survey.

3. In Great Britain unemployment insurance was required of all workers in shipbuilding and allied industries. The total number of insured workers (employed and unemployed) was provided monthly in the Ministry of Labour Gazette. Casual employment was common in the shipbuilding industry. In any given month a worker could work every day or only part of the month and often for different shipyards. In such a system separating employed from unemployed becomes difficult. For that reason the numbers 97,000 and 41,000 represent the total insured workforce which counts both employed and unemployed. From 1921 to 1936 the total insured workforce steadily declined.

4. Although Scott and Cunnison in their book *The Industries of the Clyde Valley During the War* (Clarendon Press, Edinburgh, 1924) cite a figure of 28,000 women employed in munitions in Scotland in October 1918 (p. 98), a footnote acknowledges that the number does not include women from every munitions factory and workshop, only the principal ones. Myra Baillie has identified an additional 15,000 working in other munitions firms plus an additional 4 firms for which no figures are available (Baillie, pp. 33-34). Based on these and other sources Baillie estimates that as many as 100,000 women were employed in all phases of munitions manufacturing and supporting industries throughout Scotland (Baillie, p. 34).

5. The intelligence test administered to children in either cohort was not an IQ test (SCRE, 1949, p. 119). In order to measure the IQs of all children in the cohorts, samples of children were randomly selected from both cohorts for formal IQ testing. After confirming that the demographics of the samples faithfully reflected the demographics of the cohorts, intelligence test performance was then equated to a specific IQ for each child in both cohorts.

6. A "first-draw" sample was water taken from the kitchen tap first thing in the morning before any other water in the house had been run. This is water that had sat in contact with lead all night.

7. A "day-time" sample was water taken from the kitchen tap at random times during the day before any water had been run off.

8. The topic of overalls was much discussed during the Committee on Lead Paint hearings of 1915. It was clear from testimony that some painters painted only in their street clothes and wore no overalls at all. Some employers testified that they would be willing to provide clean overalls for painters in their employ. Others would do so only under duress. In the end, the Committee recommended to the Home Secretary that painters be required to provide for the washing of their own overalls on a weekly basis (Committee on Lead Paint, p 181). When the law governing the use of lead paint in buildings was enacted in December of 1926, that recommendation was followed (MacKenzie, p. 21).

9. No relevant health information was collected from children in either Survey other than height and weight in the 1947 cohort. These data showed that children with working class parents were generally shorter and lighter than children whose parents were professional, administrative, managerial, etc (SCRE, 1953, p. 79). While the data are not diagnostic of chronic lead poisoning neither are they inconsistent. Failure to thrive, a term used to describe children who fail to achieve their expected rate of growth and development, has been associated with chronic lead poisoning among other conditions (Grant & et.al, 1980) (Schwartz, et al., 1986).

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