1. BACKGROUND

1.1 Aims of the study

The present study was initiated in 1976 in collaboration with the workers' labour union and the health care unit at Rönnskärsverken.

There was an obvious awareness among the representatives that many of their fellow-workers had died 'too early', and they feared that this might have been due to their work environment. Their basic question was

'*How long does a Rönnskär worker live*?'

A reference group was established including representatives of the workers, the health care unit and the company. This group undertook a feasibility study to explore whether individual workers could be traced by means of registers and personal communication and knowledge. The search process is further described in section 1.5.

In collaboration with the reference group, it was decided that the study would include *all the* 3 958 *male blue-collar workers first employed before* 1967 (1928–66) *for total periods of at least* 3 *months*. The inclusion of many short-term employees would possibly have masked important differences. For a total of 3 915 workers, data were possible to collect about work history (from employment records) as well as about mortality prior to the first of January 1977.

The study is retrospective in the sense that only previous exposure and events are considered. In the analysis, however, different cohorts of workers are followed 'forwards' in the search for 'new' cases of death in combination with exposure. Thus, with this 'historical' cohort approach, the ambition was to explore

- whether mortality has been '*excessive*' among workers at Rönnskärsverken,
- what *causes* of death have occurred more often than 'normal', and
- whether a deviating mortality pattern can be linked to certain work *sites* within the smelter and/or to certain *time periods*.

It is obvious that a true picture of the causal mechanism underlying the *individual* worker's illness-exposure pattern cannot be established. As a point of departure and as a complement to any later interpretations, it is therefore necessary to point out some of the study's inherent problems, as well as some of its merits and future perspectives.

Mortality—not morbidity. Job exposure need not be fatal. Health examination or interview data have not been collected. However, a special study of cancer incidence has later been performed (Chapter 16).

The individual behaviour. In addition to the external environmental risk pattern, e.g. work exposure and air pollution, there are internal life-style factors determining the health of the individual. The covariation between the internal and external determinants, e.g. between smoking and occupational exposure, has to be accounted for. Individual smoking data have therefore been collected as part of a case-referent study within the cohort. This has made it possible to ascertain whether smoking has any confounding effect (if certain exposure groups smoke more or less than others) and/or any modifying effect (implying an extra risk among smokers).

Not only one cause. The relationship between exposure and disease is of course not only a bivariate problem where one disease is caused solely by one single exposure. Real life situations are complex and a more advanced statistical view has to be adopted. This report follows mainly a simplistic approach but an illustration of some multivariate techniques will also be made (Chapters 3 and 12).

Quality of exposure data. It would be highly desirable to have individually linked quantitative exposure data by place and calendar time. This would enable us to make dose–response interpretations, in the proper sense of the words. Such data are, however, very rare.

Exposure influences health—what about the reverse? Whilst the 'healthy worker' effect, originating in the selection of healthy persons for employment, is normally recognized, less attention seems to have been paid in the literature to the selection arising when exposure is interrupted due to perceived or medically diagnosed ill health. This has been labelled the 'survivor population' effect (Fox and Collier 1976, Östlin, 1990) and will consequently dilute any dose–response relationship.

Today's morbidity—yesterday's exposure. Due to the long latency of many work-related diseases, most deaths in the study group have occurred among men already exposed in the 1930s. The collected information constitutes a valuable database that can be updated with quite limited resources. As already mentioned in the preface, additional information has been collected concerning all workers who died 1977–1982. Further follow-up of the original cohort as well as the inclusion of other groups of workers, e.g. those later employed or white-collar workers, are important for the monitoring and assessment of changes in the working conditions at the plant.

1.2 The Rönnskär story

Rönnskärsverken is a copper smelter in the county of Västerbotten in north-east Sweden (Fig. 1.1). Established in 1928 to process ore from the Boliden mine, it has been labelled 'Sweden's dirtiest industry', where half of the periodic table is said to be represented. The ore is highly complex, heavily composed of metallurgic concentrates of copper, lead, zinc, gold and silver but also of such contaminants as cadmium, arsenic and mercury.

On 20 December, 1924, a local newspaper wrote:

> '*Exploratory drilling for ore has been going on since 9 November in Skellefteå parish, near the village of Bjurliden . . . The first borehole that went down 60 m yielded nothing. A second hole, put down about 300 m from the first, struck ore at a depth of 25 m . . . The deposit consists mostly of iron pyrite, but also of some copper pyrites*'.

A month later it was revealed that the ore not only contained copper but was also rich in silver and gold.

> '*There was, however, another side to the coin. The arsenic content was also very high, which somewhat dampened the enthusiasm.*' (Ek, 1975)

The Boliden mine started production in 1926. Due to its high arsenic content (almost 15%) the ore could not be processed in an ordinary smelter, but had to be transported to a special smelter on the American west coast, at the Tacoma smelter in the State of Washington. In all, some 80 000 tons of ore were exported.

It was soon realized that, in order to expand, there was a need for a specially equipped smelter close to the mine.

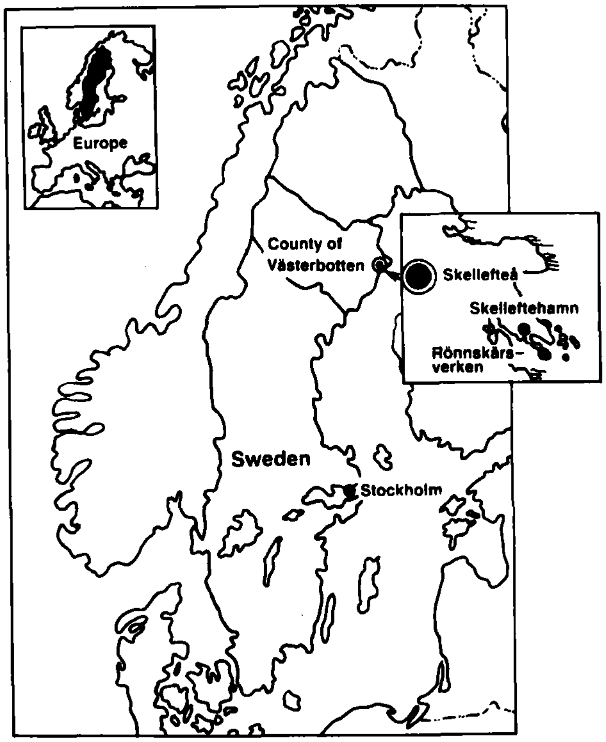

Fig. 1.1. The Rönnskär copper smelter is located in north-east Sweden.

Initially, an annual capacity for smelting 75 000 tons was envisaged.

Towards the end of 1927, Skellefteå municipal council offered to sell the islands of Rönnskär and Hamnskär, together with a large area of water, for the modest sum of 1 000 SEK. The decision to establish the smelter on what is now a peninsula was, apart from its favourable location for transportation, mainly due to meteorological circumstances. The prevailing winds would take the emissions and pollutions north, south and out to sea. The wind seldom blows landwards—towards the municipality of Skelleftehamn.

An early awareness of the potential hazards involved in the establishment of such an industry was also demonstrated in the agreement signed by representatives of the municipal council and the company:

> '*The town exempts the company from claims for compensation concerning possible damages to land belonging to the town that directly or indirectly might be caused by the company*'.

A largely new smelting process was designed by experts within the company, after which the construction of the smelter began in 1928 and production commenced in 1930. The unrefined ore was transported by rail from the mine to the smelter where, after being crushed, it was roasted in order to drive off the arsenic and most of the sulphur in the form of gas. This gas was then cooled and cleaned, the raw arsenic trioxide precipitated and the sulphur dioxide dispersed via the smoke stack. A reverberatory furnace then smelted the calcine and the slag was drawn off into tubs and dumped into the sea. The resulting material, consisting of copper and iron sulphides, was poured into a converter where the sulphur vaporized. The process continued until the converter was entirely filled with blister copper, i.e. crude copper with gold and silver.

Copper was initially the main product but, since the ore was not refined, large quantities of arsenic and sulphur were also derived. The arsenic content immediately became a central problem calling for a solution. Until 1931, the arsenic was mixed with cement to make concrete blocks which were sunk into the Gulf of Bothnia. Starting in the spring of 1931, arsenic was stored awaiting its further use in production. Some years later, processes were developed to permit the further refining of the raw arsenic into saleable products.

> '*The period of development that now started for Boliden also brought uneasiness in its train. One reason for this was the extremely rapid rate of expansion, especially when considered in relation to the size of the ore body. The mine might be exhausted in about ten years. And no one could say what the effects of the forced expansion of an almost untried plant might be, either on the workers or on the environment.*' (Ek, 1975)

1.3 Some early indicators of environmental hazards

Before further analysis is carried out, a description is required of the Rönnskär milieu in an historical perspective. Such a document has been submitted to us by Mr Åke Nygren, chief work engineer at Rönnskärsverken (Nygren, 1980). This has served as a basis for a periodic classification of calendar time for the different work sites, which will be used later to assess the 'dose pattern' in relation to each worker's job history.

The description is based on historical documents and protocols from the protection committees and on various compilations and papers since the early thirties. It is also based on interviews with workers, foremen and managers.

Measurements undertaken by The National Institute of Public Health (Folkhälsan) have served as points of departure for the quantification of environmental data. Later measurements were made by the company. Further information has been gathered from the reported sick-leave statistics during the thirties.

The visible health problems due to work environment at Rönnskärsverken in the early thirties were dominated by the so called gas and etching injuries. These were present from the very beginning. Sick-leave was the general recommendation. In 1932 it was reported that 8.7% of the working days were lost through such injuries, but certain departments showed figures as high as 20–30%.

Etching injuries were caused by raw arsenic soured by sulphuric acid. The arsenic workers were mostly exposed, especially those engaged in gas purification. The injuries occurred on damp parts of the body and in the face. Etching injuries were also caused by refined arsenic, but in a more 'insidious' way when sulphuric acid was not present.

Septum perforations were caused when handling raw as well as refined arsenic. Some considered the combination of high arsenic and sulphur dioxide concentrations to be particularly hazardous. One employee who worked both at the roasters and at the gas purifiers had septum perforations within 6 months in 1930. The number of reported perforations reached 56 by 1938 and 109 by 1949. During the sixties, 42 persons were reported to have been treated for nasal injuries, 6 of whom were said to have perforations. In the seventies, however, these injuries appear to have been rare.

Gas injuries attacking the respiratory organs were often combined with etching injuries, especially among those who worked at the roaster departments, at the copper-smelting furnace and at the converter hall, where high concentrations of sulphur dioxide were emitted. Arsenic dust and sulphur trioxide were probably also contributive. At the sulphur works (closed in 1943) the highest single sick-leave figure of 30% was reported.

Allergic reactions caused by raw as well as refined arsenic, nickel injuries similar to carbon monoxide poisoning and chromatic etching injuries were also common.

The causes of these injuries were multiple. The arsenic content of the ore was sometimes as high as 20% and in the thirties many thousands of tons of raw arsenic were passed through the gas purifiers. Initially, the ore was smelted without dressing, which caused a high sulphur content in the roasting process. The roasting goods also contained quantities of sulphuric acid, sometimes as much as 20%.

The wagons with roasting goods were propelled by hand until 1937, when electric trucks were introduced. The arsenic was also handled manually to a large extent during the early years and even into the forties.

Rinsing of the gas conduits also caused many problems. Thus, one day in February 1932, 65 men had to take sick-leave after having cleaned the gas pipelines.

The ***ventilation*** was very poor in all departments, but conditions were worst at the roasters, at the copper-smelting furnace and in the converter hall.

Labour was usually recruited from farmers, lumbermen and unskilled workers, who were unaccustomed to environmental problems of this kind. They were used to breathing freely, without fear.

'Boliden's expansion in the early thirties, a period of depression and unemployment, was a peculiar phenomenon. It brought to the whole district, and especially to the town of Skellefteå, an increase in population, taxable income, purchasing power and so forth, that was, for the time, exceptional. It all depended on gold . . . . and human perseverance.' (Ek, 1975)

There was also a general ***lack of protective equipment*** before the war. Initially, the face was protected by a piece of cloth with a pad, later by a mask with a bag. Small pieces of wadding were put in the nose when working with refined arsenic. Gradually the workers learnt to avoid the worst gas dust but, as long as the wagons had to be pushed by hand through areas filled with gas, it was almost impossible to escape completely. Some workers even believed that using a mask was more harmful since it made them breathless and thereby increased the inhalation of dust.

Table 1.1 shows an a priori agreed classification of the main sites within the smelter. Departments 6–16 are listed in approximately the order through which copper production proceeds. In departments 17 and 18 crude arsenic is processed into pure arsenictrioxide, white arsenic, and pure arsenic is processed into arsenates and metallic arsenic. Lead is processed in department 21 while departments 23–26 have service functions. Table 1.1 also presents an attempt to construct an exposure index. For each work site the running period has been divided into three time periods. Within each period exposure to various substances has been assumed to be fairly constant. For each period and place of work, exposure has been estimated relative to the present hygienic limit value. The estimations have been made by the company's own experts and should of course be judged critically and regarded as rough estimates. However, with these reservations, it does give an opportunity to perform a dose-response analysis.

Workers employed at Rönnskärsverken have been subject to medical studies since the thirties. The first study was undertaken in 1937 (Bursell and Inghe, 1937) by two medical students but was never published. Based on personal interviews with some of the workers, the results were claimed not to be 'scientific'.

Sjöstrand (1947) was the first to publish medical data on workers at the smelter. Among 180 workers, employed for at least 8 years, he found that subjective respiratory problems and reduction at physical work capacity were reported mainly among workers at the roasting furnaces, the reverberatory furnace and at the converter hall. It was medically ascertained in a subsample of twenty workers, that most of those who reported pronounced subjective troubles, had chronic changes, often with signs of atrophy of the mucous membranes. More than half of them showed signs of emphysema. The subjective reduction in physical work capacity was objectively verified on working tests and the changes were considered to have been of the kind caused by exposure to corrosive gases and dust. These findings on what has been labelled the 'Rönnskär disease' have found support in later studies, but so far have only been published in Swedish.

Lundgren et al. (1951) were the first to describe the 'Rönnskär disease'. Their investigation was based on data concerning 1 450 workers. When compared with a control group from the timber industry, this group of Rönnskär workers had significantly more symptoms of respiratory problems, especially in the nose, throat, epipharynx, larynx and trachea. Among 187 workers who had their lungs x-rayed, only one out of five were classified as normal. Arsenic trioxide was thought to cause the changes in the mucous membranes. Those working with arsenic refining had more septum perforations (without changes in the lower respiratory organs) than workers at the roasters. The latter, instead, had atrophic changes of the bronchia.

Warfvinge (1952) described the x-ray picture of the Rönnskär bronchitis. He displayed the difference between the chronic bronchitis caused by chemical agents and the chronic infectious bronchitis, and suggested that the x-ray could be used as supplementary information in matters of insurance claims.

Lundgren (1954) showed how subjective symptoms reported by the workers were related to work sites within the smelter. Those working in the open air had few symptoms while arsenic workers, roasters and workers at the converter hall had nasal symptoms, like nose-bleeding and septum perforations, and respiratory problems such as coughing, hoarseness and breathlessness.

Holmqvist (1951) related occupational dermatosis to arsenic exposure which, in a subsequent case–referent study by Axelsson et al. (1978), was also found to be significantly associated with an increased mortality of lung cancer.

Rehnlund (1978) reported a higher proportion of lung cancer mortality, especially among roasters, in comparison with the surrounding region. He concluded that lung cancer is caused by a combination of smoking, SO_2 and possibly arsenic, in that order. He also commented that SO_2 levels in the forties were approximately 20 times higher than during the period 1958–64 (see also Table 1.1).

In 1975, the Swedish government ultimately initiated further investigations of the smelter environment. Since then some 50–60 different environmental studies on the smelter surroundings (animals, air, water, vegetation and population) have been made as well as on the workers themselves (perceived health, mortality, life expectancy, reproduction).

A summary was thus made of the present knowledge on the type of emissions from the smelter and their environmental and reproductive effects (Beckman, 1978). An increased occurrence of chromosomal aberrations was found

Table 1.1

Classification of the main work sites within the smelter, their respective running periods and potential hazards as measured by estimated mean exposure values

Work site No.	Work process	Running periods			Total dust (mg/m^3)			Arsenic (mg/m^3)			Sulphur dioxide (ppm)			Nickel (mg/m^3)			Lead (mg/m^3)		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Ore dressing	34–39	40–49	50–54	2	2	2	0.15	0.05	–	–	–	–	–	–	–	–	–	–
2	Found works	28–32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	Sulphur plant	35–43	–	–	30	–	–	2.0	–	–	100	–	–	–	–	–	–	–	–
4	External works	30–39	40–49	50–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	Mason	30–39	40–49	50–	30	10	5	1.0	0.2	0.05	10	6	3	–	0.3	–	–	–	–
6	Conc. delivery	30–39	40–72	73–	10	2	–	0.15	0.05	–	5	–	–	–	–	–	–	–	–
7	Copper roaster	30–39	40–49	50–	150	20	5	5.0	1.0	0.2	300	30	5	–	1.0	–	–	–	–
8	Roaster gas purifier	30–39	40–49	50–	400	90	30	50.0	5.0	1.0	50	10	–	–	–	–	–	–	–
9	Reverb/electric copper furnace	30–39	40–49	50–	60	10	5	4.0	0.5	0.15	300	30	5	–	0.5	–	–	–	–
10	Converter hall	30–39	40–49	50–	40	5	2	2.5	0.4	0.1	200	20	3	–	0.5	–	–	–	–
11	Anode furnace	30–39	40–49	50–	40	5	2	2.5	0.4	0.1	200	20	3	–	0.5	–	–	–	–
12	Coal crusher	30–39	40–49	50–	40	5	2	2.5	0.4	0.1	200	20	3	–	0.5	–	–	–	–
13	Electrolysis plant	32–39	40–49	50–	–	–	–	–	–	–	–	–	–	–	0.5	–	–	–	–
14	Cathode furnace/casting	32–53	54–77	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15	Nickel smelter	42–45	–	–	50	–	–	–	–	–	–	–	–	5.0	–	–	–	–	–
16	Precious metals plant	33–55	56–	–	2	2	–	–	–	–	–	–	–	–	–	–	–	–	
17	Arsenic refinery/metal plant	33–39	40–61	62–77	100	10	5	10.0	1.0	0.1	–	–	–	–	–	–	–	–	–
18	Arsenic salt/selenium works	33–45	46–69	70–	10	5	1	2.0	0.25	0.05	–	–	–	–	–	–	–	–	–
19	Ball foundry	49–62	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20	Sulph acid works	53–	–	–	–	–	–	–	–	–	10	–	–	–	–	–	–	–	–
21	Lead depts	40–59	60–69	70–	–	–	–	0.1	–	–	5	5	–	–	–	–	2	0.5	0.1
22	Central laboratory	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	Machine shop	30–39	40–49	50–	30	3	2	2.5	0.25	0.05	30	6	2	–	–	–	–	–	–
24	Electric shop	30–39	40–49	50–	30	3	2	2.5	0.25	0.05	30	6	2	–	–	–	–	–	–
25	Transportation dept	30–39	40–49	50–	30	3	2	2.5	0.25	0.05	30	6	2	–	–	–	–	–	–
26	Building dept	30–39	40–	–	10	3	–	0.25	0.05	–	10	1	–	–	–	–	–	–	–
27	Various large depts	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28	Various small depts	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

among workers exposed to arsenic and lead. A comparison between different areas located at various distance from the smelter showed that the highest frequency of spontaneous abortions (11%) occurred close to the smelter. Birth weights of the offspring of women working or living close to the smelter were significantly lower than expected and furthermore, occupational exposure seemed to increase the risk of congenital malformations.

In a study by Pershagen, Elinder and Bolander (1978), two parishes in the vicinity of the plant were compared with a reference area. The lung cancer mortality was significantly higher in the exposure area but not, however, after the exclusion of the occupationally exposed. In a later case–referent study (Pershagen, 1985) it was statistically verified, however, that lung cancer excess risks still prevailed after accounting for smoking as well as job history.

1.4 The workers

The historical character of the study is illustrated in Fig. 1.2. A quarter of the 3 915 workers were already employed before 1935 and half before 1945. The vertical distance between the two upper curves gives the number of active workers by calendar year. The lowest curve shows that approximately half of the 953 deaths occurred after 1967.

In Table 1.2, the same classification of work sites is used as in Table 1.1 and the distribution of the 3 915 workers in the study group is now shown with regard to *work site*, *number of years* worked and *when* the exposure took place at the various sites. Table 1.2 also illustrates the mobility between jobs, as displayed by the number of years worked per site and the time period during which certain work contributes to the exposure. The 3 915 workers have spent an average of 12.9 years at the Rönnskär smelter. Of the total exposure, 39% occurred before 1950. Thirty per cent of the workers have had only one type of job within the smelter while 35% have worked in five or more places. As

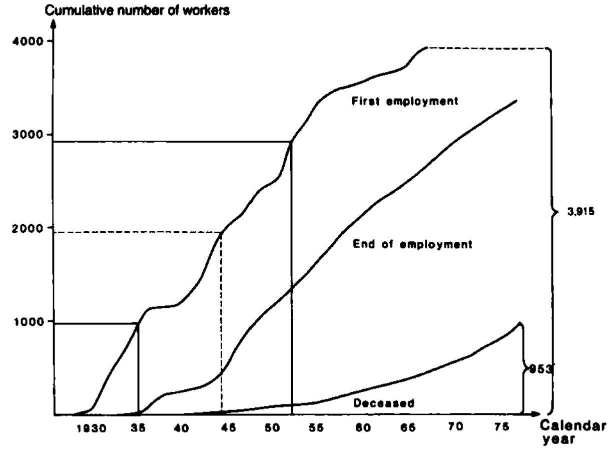

Fig. 1.2. Cumulative distributions in the study group of year of first employment, end of employment and death.

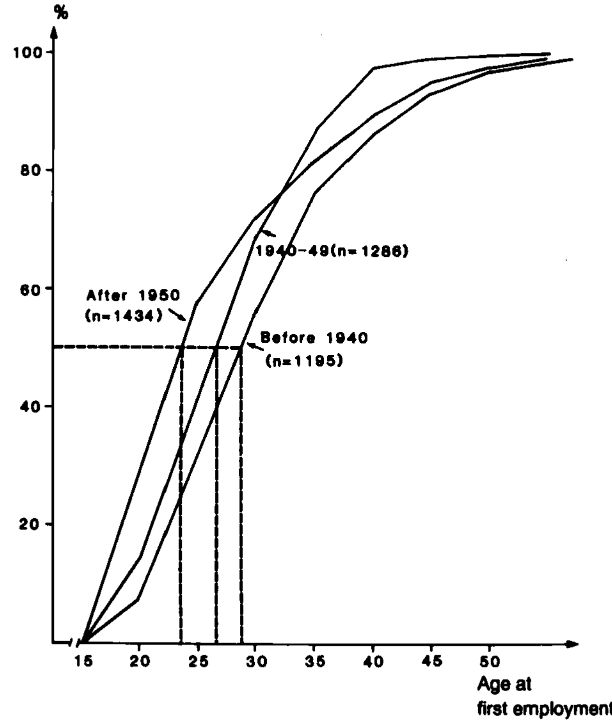

Fig. 1.3. Cumulative distributions of age at first employment during different time periods.

many as 546 workers (14%) have changed job within the smelter ten times or more. Almost 60% of all job periods were shorter than one year while 8% lasted for ten or more years.

During the follow-up period there have also been changes in the age of workers when first employed (Fig. 1.3) – the earlier the year of employment, the older the employee. Median ages on appointment were 29, 27 and 24 years respectively during the time periods before 1940, 1940–49 and after 1950.

1.5 How the data were obtained

Sweden has a long tradition of registers with an experience in routine data collection which is probably unique in the world. In principle, complete demographical data exist from 1749 with regard to the size and composition of the population as well as the yearly numbers of births and deaths. Originally, data on causes of death were collected by the Swedish clergy for the period 1751–1830. From 1831 onwards it was only compulsory to report the cause of death in four cases, namely during child birth, from smallpox, suicide and accidents. Among the remaining causes only major epidemics were reported to central authorities. It was not until 1903 that the number of deaths were given by causes in combination with both sex and age. Since 1911, annual reports on 'Causes of deaths' have been published.

Table 1.2

Distribution of the number of workers, their total exposure time on main work sites and calendar time

Work site No.	Work process	No. of workers	No. of years/ worker	% of exposure during years				
				-1939	40-49	50-59	60-69	70-
1	Ore dressing	427	3.4	26	53	21	0	0
2	Found works	401	1.9	98	2	0	0	0
3	Sulphur plant	219	2.7	68	31	1	0	0
4	External works	1 274	2.7	8	23	34	32	3
5	Mason	117	7.1	12	36	24	21	7
6	Conc. delivery	188	2.3	24	46	20	7	3
7	Copper roaster	560	3.4	34	30	18	14	4
8	Roaster gas purifier	420	3.5	18	33	24	20	5
9	Reverberatory/electric copper furnace	647	3.1	28	34	18	15	5
10	Converter hall	872	2.9	27	35	18	13	6
11	Anode furnace	507	2.6	7	35	34	18	5
12	Coal crusher	160	2.8	39	41	11	3	5
13	Electrolysis plant	391	5.7	8	26	34	21	10
14	Cathode furnace/casting	451	4.0	5	19	38	28	11
15	Nickel smelter	310	1.2	0	100	0	0	0
16	Precious metals plant	111	7.0	5	17	29	32	17
17	Arsenic refinery/metal plant	503	3.5	23	14	27	23	13
18	Arsenic salt/selenium works	452	3.6	5	22	34	25	14
19	Ball foundry	128	2.3	0	2	80	18	0
20	Sulph acid works	106	4.1	0	0	25	45	30
21	Lead depts	708	4.2	0	18	43	27	11
22	Central laboratory	261	3.7	1	1	34	43	21
23	Machine shop	757	9.2	13	21	27	27	12
24	Electric shop	468	6.7	8	19	32	27	14
25	Transportation dept	1 018	5.0	4	26	34	25	11
26	Building dept	1 216	3.8	5	24	37	25	9
27	Various large depts	903	3.0	24	17	31	19	8
28	Various small depts	393	3.1	2	19	12	38	28
	All work sites	3 915	12.9	14	25	29	22	10

As mentioned in section 1.1, a feasibility study was first undertaken to explore whether individual workers could be traced by means of employment registers, personal communication and knowledge as well as via national and local population registers. This study included the first 100 workers employed at the smelter in the early thirties, all of whom could be traced after an intensive but more or less informal search. A systematic strategy had to be worked out for the main study and this is illustrated in Fig. 1.4. This figure shows in summary form how information has been gathered. Using employment records, information was sought for almost all the 3 958 workers that, according to the definition (see 1.1) were to be included in the study group.

The system of civic registration numbers, established in 1947 for all individuals, facilitates record linkages and provided points of departure in the search process. In a substantial proportion of cases, however, information about civic registration number was lacking, especially for workers first employed before 1947. Supplementary information has therefore been gathered from regional manual registers and via personal visits to and correspondence with parish registrar's offices all over Sweden. More often than not, migration implied that as many as ten different registrar's offices had to be contacted before a given individual could be traced. Today, microfilmed and computerized registers are very useful but they were not available at the time of this data collection.

After having completed the list of all but 15 of the 3 958 workers for whom civic registration numbers were traced and deleted 4 duplicates, the individuals were sought for in the register of the current Swedish population alive at the 1st of January 1977 (available at Statistics Sweden).

By means of the cause of death register at the Statistics Sweden and the local parish registers (for those deceased before 1961), it was confirmed that 953 workers had died. Today the cause of death register is computerized as of deaths 1952 and onwards. The causes of death were

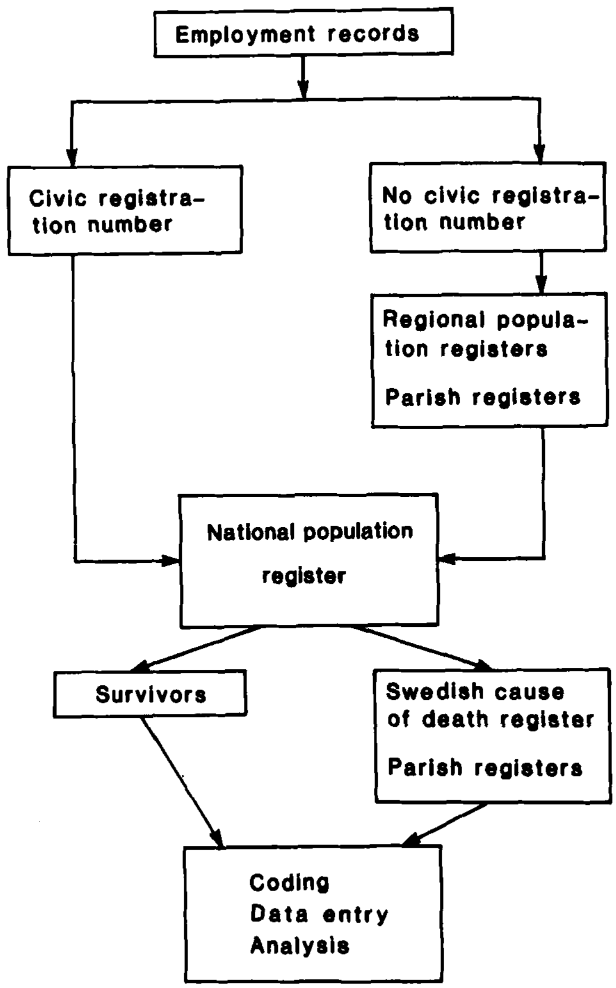

Fig. 1.4. A flow-chart for the search process.

assessed according to the WHO International Classification system. It could also be deduced that 19 workers had emigrated and a further five could be traced to the so-called "register of 'non-existent' persons". Thus, 3 915 of the 3 958 workers (99%) have been identified. This search procedure took about 6 months for a qualified secretary.

The quality of the cause of death statistics has been the subject of a number of evaluation studies. Reviewing the records of 1 156 deaths, De Faire et al. (1976), conclude that data are reasonably valid for use in epidemiologic studies with regard to most cancer forms, cerebrovascular disease, ischaemic heart disease, bronchitis, asthma and emphysema, accidents and suicides—but not for diabetes mellitus, alcoholism, mental diseases and 'rheumatic and other heart diseases'.

For each individual, work-history data were collected from employment records. The individual exposure was coded as a combination of length of exposure at each work site and calendar time. Thus, the available information makes it possible to follow each worker 'historically' from first employment at Rönnskärsverken, via different jobs at the smelter, until either the 1st of January 1977 (and in Chapter 16 until the 1st of January 1983) or prior death (Fig. 1.5).

In January 1976, the very first contacts were established with representatives of the workers' labour union, the health care unit at Rönnskärsverken and the company. After about $1\frac{1}{2}$ man-years of work the first results from the study could be presented to the workers and their representatives at a meeting on the 19th of September 1978 (Wall et al., 1978).

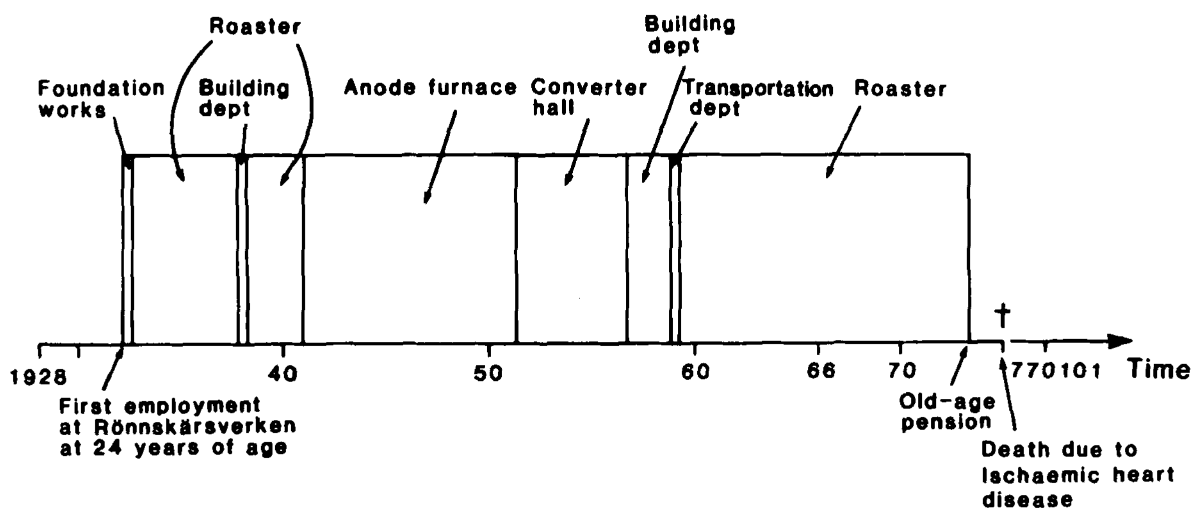

Fig. 1.5. A work-history case at Rönnskärsverken.