

Mortality in employees at a New Zealand agrochemical manufacturing site

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Background	Previous studies at the Dow AgroSciences (Formerly Ivon Watkins-Dow) plant in New Plymouth, New Zealand, had raised concerns about the cancer risk in a subset of workers at the site with potential exposure to 2,3,7,8-tetrachlorodibenzo- <i>p</i> -dioxin. As the plant had been involved in the synthesis and formulation of a wide range of agrochemicals and their feedstocks, we examined the mortality risk for all workers at the site.
Aims	To quantify the mortality hazards arising from employment at the Dow AgroSciences agrochemical production site in New Plymouth, New Zealand.
Methods	Workers employed between 1 January 1969 and 1 October 2003 were followed up to the end of 2004. Standardized mortality ratios (SMRs) were calculated using national mortality rates by employment duration, sex, period of hire and latency.
Results	A total of 1754 employees were followed during the study period and 247 deaths were observed. The all causes and all cancers SMRs were 0.97 (95% CI 0.85–1.10) and 1.01 (95% CI 0.80–1.27), respectively. Mortality due to all causes was higher for short-term workers (SMR 1.23, 95% CI 0.91–1.62) than long-term workers (SMR 0.92, 95% CI 0.80–1.06) and women had lower death rates than men. Analyses by latency and period of hire did not show any patterns consistent with an adverse impact of occupational exposures.
Conclusions	The mortality experience of workers at the site was similar to the rest of New Zealand.
Key words	Chemical industry; cohort studies; dioxins; mortality; occupational exposure; risk assessment.

Introduction

The former Ivon Watkins-Dow plant, now Dow AgroSciences New Zealand [1], has been in operation at the same site since 1962 making a diverse range of agrochemical products. Initially, the plant manufactured 2,4-dichlorophenoxy acetic acid and later 2,4,5-trichlorophenoxy acetic acid (2,4,5-T) and 4-chloro 2-methylphenoxy acetic acid. The 2,4,5-trichlorophenol feedstock for 2,4,5-T was manufactured from 1969, and smaller amounts of 2-methyl-4-chlorophenoxybutyric acid were manufactured from the early 1970s. In addition to phenoxy herbicides, numerous other pesticides and chemical raw materials were handled on the site: these included the sodium salt of

2,4,6-TCP, picloram, atrazine, simazine, amitrole and dichloropropionic acid. In 1987, the TCP plant closed and 2,4,5-T production ceased in 1988. The dioxin, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), can be an unwanted contaminant in TCP and 2,4,5-T. Figure 1 provides the chemical structure of TCDD, TCP and 2,4,5-T. The current manufacturing activities are mostly centred around the formulation and packaging of insecticides, herbicides, fungicides and spraying oil.

Because of the potential exposure to TCDD, some workers at the plant were included in an international cohort of 18 910 phenoxy herbicide sprayers and production workers designed to evaluate health effects and exposure to TCDD. This study was carried out in 10 countries by the International Agency for Research on Cancer and the results, published in 1991, indicated that soft tissue sarcomas and non-Hodgkin's lymphoma were greater than expected among workers with exposure to 2,4,5-T [2].

The New Plymouth study subgroup included 1038 men and women who worked at least 1 month between 1969 and 1984, with vital status follow-up to 1987.

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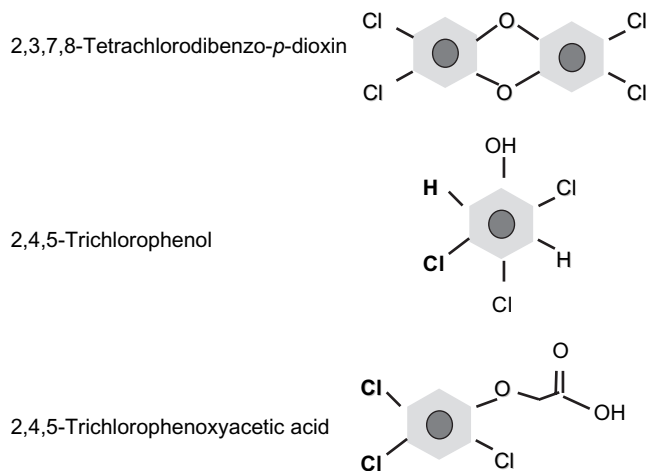


Figure 1. Chemical structures for TCDD, 2,4,5-trichlorophenol and 2,4,5-T.

Workers were classified according to the main study criteria as exposed to phenoxyes, probably exposed, with 'unknown exposure' or unexposed. There were 782 employees who were considered exposed to phenoxy herbicides or trichlorophenol, with some workers involved in warehousing of products at other New Zealand sites. The unexposed workers were employed outside the production areas such as in administrative positions. This study found a small excess of all cancers combined but no increase in lung cancer, soft tissue sarcoma or non-Hodgkin's lymphoma, cancers which have been associated with TCDD exposure in some studies. The study was recently updated with follow-up to 2000 [3]. The findings were similar to the earlier study although there were more multiple myeloma deaths than expected among workers with potential dioxin exposure.

Given these reports about the health risks at the New Plymouth site, the principal aim of this study was to quantify the overall mortality hazard from employment there. The objectives were to identify and include all the employees who worked at the plant between 1969 and 2003, follow the vital status of these workers to the end of 2004 and determine if workers at the site have mortality levels different from the New Zealand population. This is the first study in a series which will examine the health of these workers.

Methods

Work history records were used to identify all the employees who worked for at least 1 day at the New Plymouth site between 1 January 1969 and 1 October 2003: the latter being the date that the work history records were collected. In the analysis, 23 individuals who had missing dates of birth were excluded, and 9 people lacking information on sex were assumed to be male. The total number of workers in the study was 1754.

Vital status for each study member was determined from 1 January 1969 to 31 December 2004. The search was based on the New Zealand Health Information Service (NZHIS) Mortality Collection [4], in which deaths registered in New Zealand from 1988 onwards are held in the electronic mortality database, and data from 1970 to 1987 are archived and are available on request. Deaths occurring between 1969 and 1987 were matched to work records using an algorithm which required an exact match on date of birth and ranked minor errors in the spelling of surnames and forenames, nine being a perfect match, with eight and seven being minor differences in surname or forename. All matches were examined, and matches of seven to nine proved acceptable. From 1988 onwards, searches were based on the National Health Index number on the mortality database, unique to each individual. We then carried out additional searches based on the last known address on the employee database, following name and address changes using the Electoral Roll and Habitation Index [5], Telephone Book, Companies Office [6], 'Terranet' property information database [7] and search engines on the Internet [8,9].

Additional deaths up to 1990 were sought from the Registrar-General's Index to Deaths. If a person was not known to be alive at the study end date (i.e. on the electoral roll), an additional search was made through births, deaths and marriages. Follow-up ended on 31 December 2004, at the date of death, or for those who had left New Zealand, or could not be traced, at the date they were last known to be in the country. NZHIS provided the coded underlying causes of death for all deaths in the study [10].

The expected numbers of deaths adjusted for age, gender and calendar year were calculated using the Occupational Mortality Cohort Analysis Program [11]. The New Zealand national mortality rates, obtained from NZHIS, were used as the reference population. Standardized mortality ratios (SMRs) and exact 95% confidence intervals (CIs) were calculated for major causes of death and cancer. Person-years for the study members were accumulated across 5-year age calendar year-specific categories from the date of entry into the study until the end of follow-up. Analyses were carried out by duration of employment, sex, latency and period of hire. For the duration of employment analyses, we divided workers into two groups. The first group included workers employed for ≤ 3 months to account for seasonal and short-term workers. The second group included those workers who worked for ≥ 3 month. Latency was defined as the period between the day last worked and the date of death, the end of study date and the date lost to follow-up or emigration, whichever came first [12]. Latency of less than and greater than 15 years and period of hire pre-1976 and post-1975 were chosen to examine possible exposure effects while having a reasonable number of person-years in each stratum.

Results

From the total of 1754 eligible persons, 247 deaths were observed. Twenty-two per cent of the cohort was lost to follow-up as shown in Table 1. This included 392 individuals, among which 156 (9%) were known to have emigrated before the study end date.

Among all employees (Table 2), all cause mortality, SMR 0.97 (95% CI 0.85–1.10), and all cancer mortality, SMR 1.01 (95% CI 0.80–1.27), were close to expected levels. There were no statistically significant differences in any cause of death compared to the New Zealand population. Approximately, one-third of the deaths were due to heart disease and were close to expected levels (SMR 1.02, 95% CI 0.81–1.27). There were more than expected numbers of deaths due to cancers of the digestive system (27 observed versus 22.8 expected) and lymphohaematopoietic cancers (8 observed versus 6.6 expected). On the other hand, some specific cancers occurred at less than expected rates, such as lung cancer (15 observed versus 17.3 expected), breast cancer (2 observed versus 3.5 expected) and prostate cancer (3 observed versus 5.6 expected).

The rates for those who had worked at the site for <3 months (short-term employees) were generally higher than those who worked for ≥3 months (long-term employees), short-term employees showing an all causes SMR of 1.23 (95% CI 0.91–1.62). This included a statistically significant excess of all cancers of the digestive system, SMR 2.52 (95% CI 1.15–4.78), reflected by an increased risk for all the subsites in this category except cancer of the large intestine. The increased risk was not only limited to malignant neoplasm but also occurred from heart disease, cirrhosis of the liver and motor vehicle accidents. Conversely, the long-term employees exhibited, in general, lower mortality rates with most causes at less than expected rates. These included all causes (SMR 0.92, 95% CI 0.80–1.06), all cancers (SMR 0.98, 95% CI 0.75–1.26), cancers

of the digestive system (SMR 0.94, 95% CI 0.56–1.48) and heart disease (SMR 0.94, 95% CI 0.72–1.20). All eight lymphohaematopoietic cancers in the cohort were found in the long-term employees, producing a slightly elevated SMR of 1.21 (95% CI 0.52–2.39).

Those with ≥15 years of latency had lower mortality from all causes, all cancers and all heart disease as shown in Table 3. Deaths from all lymphohaematopoietic tumours remained raised in this group (7 observed versus 4.7 expected), mostly as a result of non-Hodgkin's lymphoma (SMR 2.09, 95% CI 0.57–5.35) and multiple myeloma (SMR 2.10, 95% CI 0.26–7.60). Accidents, including motor vehicle accidents, were also greater than expected, as were asthma, nephritis and nephrosis.

There were only 26 deaths in those employed after 1975, as shown in Table 4, with all causes, all cancers and all heart disease SMRs at 0.74 (95% CI 0.48–1.08), 0.62 (95% CI 0.25–1.28) and 0.60 (95% CI 0.20–1.41), respectively. Those employed prior to 1976 had SMRs close to expected levels for the same causes.

There were fewer deaths among females (27) than males (220) as shown in Table 5. Females had lower all causes mortality, SMR 0.68 (95% CI 0.45–1.00), than males, SMR 1.02 (95% CI 0.89–1.17). A decrease in female all cancer mortality was evident, with an SMR of 0.52 (95% CI 0.22–1.02), as compared to a male rate of 1.14 (95% CI 0.90–1.45). Cause-specific rates among the women were, however, imprecise due to the small numbers of observed and expected deaths.

Discussion

We found overall that workers in the study population had death rates similar to the rest of New Zealand. Employment duration accounted for the greatest differences in observed mortality rates: relative to long-term workers, those who were employed for <3 months had higher death rates for many causes including all causes, all cancers, ischaemic heart disease and all accidents. In addition, among these short-term workers, cancers of the digestive system were greater than expected especially for rectal cancer, oesophageal cancer and pancreatic cancer. In contrast, workers employed for >3 months had mortality levels consistent with the rest of New Zealand. These findings of higher death rates among short-term workers have been reported in other studies, attributed to the healthy worker effect [13] and lifestyle factors, especially alcohol use and tobacco [14–16]. Since the long-term workers had mortality and cancer rates similar to the New Zealand population, it is unlikely that brief workplace exposures contributed significantly to the mortality rates seen in the short-term workers.

Women working at the site had low mortality rates compared to women in the rest of New Zealand (SMR 0.68, 95% CI 0.45–1.00). These low rates among women

Table 1. Vital status follow-up of study group

Category	n (%)	PY contributed
Alive ^a	1115 (64)	31 084
Dead	247 (15)	4579
COD provided by NZHIS	247	
Lost to follow-up ^{b,c}	392 (22)	2679
Unknown	236 (13)	
Emigrated	156 (9)	
Total	1754	38 343

COD, cause of death; PY, person-years.

^aFifteen people died after the end-of-study date.

^bThree people died overseas after their end-of-follow-up date, which was determined as the end of their last NZ Dow job or last known date of NZ residence.

^cPerson-years potentially lost to follow-up = 7735.

Table 2. SMR and 95% CI by duration of employment

Cause of death	Employment duration								
	≥3 months			<3 months			All durations		
	Obs/exp	SMR	95% CI	Obs/exp	SMR	95% CI	Obs/exp	SMR	95% CI
All causes of death	197/213.7	0.92	(0.80–1.06)	50/40.6	1.23	(0.91–1.62)	247/254.4	0.97	(0.85–1.10)
All malignant neoplasms	62/63.3	0.98	(0.75–1.26)	14/11.8	1.19	(0.65–2.00)	76/75.1	1.01	(0.80–1.27)
Cancer of buccal cavity and pharynx	3/1.2	2.45	(0.51–7.15)	0/0.3	–	(0.00–14.46)	3/1.5	2.03	(0.42–5.92)
Cancer of digestive organs and peritoneum	18/19.2	0.94	(0.56–1.48)	9/3.6	2.52*	(1.15–4.78)	27/22.8	1.19	(0.78–1.73)
Cancer of oesophagus	3/1.7	1.73	(0.36–5.05)	2/0.3	6.05	(0.73–21.86)	5/2.1	2.42	(0.79–5.65)
Cancer of stomach	5/3.1	1.61	(0.52–3.75)	1/0.6	1.75	(0.04–9.75)	6/3.7	1.63	(0.60–3.55)
Cancer of large intestine	3/5.9	0.51	(0.11–1.49)	0/1.1	–	(0.00–3.49)	3/6.9	0.43	(0.09–1.26)
Cancer of rectum	5/3.3	1.51	(0.49–3.52)	3/0.6	4.88*	(1.01–14.25)	8/3.9	2.03	(0.88–4.01)
Cancer of biliary passages and liver primary	1/1.6	0.64	(0.02–3.58)	1/0.3	3.08	(0.08–17.19)	2/1.9	1.06	(0.13–3.85)
Cancer of pancreas	1/2.6	0.39	(0.01–2.18)	2/0.5	4.31	(0.52–15.58)	3/3.0	0.99	(0.21–2.90)
Cancer of respiratory system	16/15.5	1.03	(0.59–1.67)	2/2.8	0.72	(0.09–2.60)	18/18.3	0.98	(0.58–1.55)
Cancer of larynx	2/0.4	4.71	(0.57–17.03)	0/0.1	–	(0.00–47.16)	2/0.5	3.98	(0.48–14.38)
Cancer of bronchus, trachea and lung	13/14.7	0.89	(0.47–1.51)	2/2.6	0.77	(0.09–2.77)	15/17.3	0.87	(0.49–1.43)
Malignant melanoma of skin	1/2.2	0.46	(0.01–2.59)	1/0.5	2.01	(0.05–11.18)	2/2.7	0.75	(0.09–2.72)
Soft tissue sarcoma	1/0.3	3.03	(0.08–16.89)	0/0.1	–	(0.00–49.29)	1/0.4	2.47	(0.06–13.77)
Cancer of breast (female only)	2/3.1	0.65	(0.08–2.36)	0/0.5	–	(0.00–8.14)	2/3.5	0.57	(0.07–2.06)
Cancer of cervix uteri (female only)	1/0.5	1.82	(0.05–10.15)	0/0.1	–	(0.00–42.52)	1/0.6	1.57	(0.04–8.77)
Cancer of prostate (male only)	3/4.8	0.62	(0.13–1.82)	0/0.8	–	(0.00–4.67)	3/506	0.54	(0.11–1.56)
Cancer of kidney	2/1.4	1.39	(0.17–5.03)	1/0.3	3.48	(0.09–19.39)	3/1.7	1.74	(0.36–5.09)
Cancer of bladder and other urinary organs	1/1.4	0.72	(0.02–3.99)	0/0.2	–	(0.00–15.94)	1/1.6	0.62	(0.02–3.43)
Cancer of central nervous system	3/2.2	1.38	(0.29–4.03)	1/0.5	1.99	(0.05–11.10)	4/2.7	1.50	(0.41–3.83)
Cancer of all lymphatic and haematopoietic tissue	8/5.5	1.46	(0.63–2.88)	0/1.1	–	(0.00–3.32)	8/6.6	1.21	(0.52–2.39)
Hodgkin's disease	1/0.3	3.83	(0.10–21.32)	0/0.1	–	(0.00–62.04)	1/0.3	3.12	(0.08–17.37)
Non-Hodgkin's lymphoma	4/2.1	1.92	(0.52–4.91)	0/0.4	–	(0.00–8.58)	4/2.5	1.59	(0.43–4.07)
Leukaemia and aleukaemia	1/2.0	0.49	(0.01–2.74)	0/0.4	–	(0.00–8.73)	1/2.5	0.41	(0.01–2.27)
Multiple myeloma	2/1.0	1.96	(0.24–7.09)	0/0.2	–	(0.00–19.75)	2/1.2	1.66	(0.20–5.99)
Diabetes mellitus	4/4.6	0.87	(0.24–2.23)	1/0.9	1.15	(0.03–6.40)	5/5.5	0.92	(0.30–2.14)
Cerebrovascular disease	13/15.4	0.84	(0.45–1.44)	4/2.4	1.65	(0.45–4.21)	17/17.9	0.95	(0.55–1.52)
All heart disease	64/68.3	0.94	(0.72–1.20)	18/11.9	1.51	(0.89–2.38)	82/80.3	1.02	(0.81–1.27)
Ischaemic heart disease	59/58.9	1.00	(0.76–1.29)	16/10.1	1.58	(0.90–2.56)	75/69	1.09	(0.86–1.36)
Non-malignant respiratory disease	13/17.5	0.74	(0.40–1.27)	1/2.8	0.36	(0.01–2.02)	14/20.3	0.69	(0.38–1.16)
Bronchitis	2/4.5	0.45	(0.05–1.61)	0/0.7	–	(0.00–4.97)	2/5.2	0.38	(0.05–1.38)
Emphysema	2/1.6	1.23	(0.15–4.43)	0/0.3	–	(0.00–14.69)	2/1.9	1.06	(0.13–3.84)
Asthma	3/1.5	1.97	(0.41–5.77)	1/0.3	3.07	(0.08–17.10)	4/1.8	2.17	(0.59–5.55)
Cirrhosis of liver	2/1.7	1.16	(0.14–4.20)	2/0.4	5.58	(0.68–20.14)	4/2.1	1.92	(0.52–4.93)
Nephritis and nephrosis	2/1.5	1.30	(0.16–4.68)	1/0.3	3.74	(0.09–20.82)	3/1.8	1.66	(0.34–4.84)
All external causes of death	13/19.0	0.69	(0.37–1.17)	8/6.0	1.33	(0.57–2.61)	21/25	0.84	(0.52–1.28)
Accidents	10/12.7	0.79	(0.38–1.45)	7/4.0	1.74	(0.70–3.59)	17/16.7	1.02	(0.59–1.63)
Motor vehicle accidents	4/6.9	0.58	(0.16–1.49)	6/2.3	2.58	(0.95–5.60)	10/9.2	1.09	(0.52–2.00)
Suicides	2/5.3	0.38	(0.05–1.37)	1/1.7	0.59	(0.02–3.27)	3/7.0	0.43	(0.09–1.26)

Obs/exp, observed/expected.

* $P < 0.05$.

at the site are attributable to low cancer and heart disease rates. Although there were few person-years of follow-up, these low rates for women in chemical plants have been seen in other studies [17–20].

One potential limitation of this study is the 22% loss to follow-up. However, our levels of loss are similar to other New Zealand studies. Much of the loss to follow-up is due to the high rate of emigration which occurs in New

Table 3. SMR and 95% CI by latency

Cause of death	Latency					
	15 years latency			<15 years		
	Obs/exp	SMR	95% CI	Obs/exp	SMR	95% CI
All causes of death	166/175.0	0.95	(0.81–1.10)	81/79.3	1.02	(0.81–1.27)
All malignant neoplasms	53/55.0	0.96	(0.72–1.26)	23/20.1	1.14	(0.72–1.71)
Cancer of buccal cavity and pharynx	2/1.0	1.92	(0.23–6.92)	1/0.4	2.29	(0.06–12.75)
Cancer of digestive organs and peritoneum	18/16.7	1.08	(0.64–1.70)	9/6.1	1.48	(0.68–2.81)
Cancer of oesophagus	4/1.6	2.51	(0.68–6.42)	1/0.5	2.13	(0.05–11.87)
Cancer of stomach	6/2.5	2.36	(0.87–5.14)	0/1.1	–	(0.00–3.25)
Cancer of large intestine	1/5.0	0.20	(0.01–1.10)	2/1.9	1.06	(0.13–3.83)
Cancer of rectum	4/2.9	1.40	(0.38–3.59)	4/1.1	3.70*	(1.01–9.46)
Cancer of biliary passages and liver primary	2/1.4	1.43	(0.17–5.18)	0/0.5	–	(0.00–7.62)
Cancer of pancreas	1/2.2	0.45	(0.01–2.53)	2/0.8	2.45	(0.30–8.85)
Cancer of respiratory system	11/13.3	0.83	(0.41–1.48)	7/5.1	1.39	(0.56–2.86)
Cancer of larynx	1/0.3	2.87	(0.07–15.98)	1/0.2	6.50	(0.16–36.23)
Cancer of bronchus, trachea and lung	10/12.5	0.80	(0.38–1.47)	5/4.8	1.05	(0.34–2.44)
Malignant melanoma of skin	0/1.8	–	(0.00–2.01)	2/0.8	2.43	(0.30–8.79)
Soft tissue sarcoma	1/0.2	4.13	(0.10–22.99)	0/0.2	–	(0.00–22.73)
Cancer of breast (female only)	1/2.3	0.43	(0.01–2.38)	1/1.2	0.85	(0.02–4.75)
Cancer of cervix uteri (female only)	1/0.4	2.85	(0.07–15.87)	0/0.3	–	(0.00–12.98)
Cancer of prostate (male only)	3/4.8	0.62	(0.13–1.81)	0/0.8	–	(0.00–4.83)
Cancer of kidney	3/1.3	2.37	(0.49–6.93)	0/0.5	–	(0.00–8.07)
Cancer of bladder and other urinary organs	1/1.3	0.78	(0.02–4.36)	0/0.3	–	(0.00–10.55)
Cancer of central nervous system	3/1.7	1.73	(0.36–5.06)	1/0.9	1.06	(0.03–5.90)
Cancer of all lymphatic, haematopoietic tissue	7/4.7	1.48	(0.60–3.05)	1/1.9	0.54	(0.01–2.98)
Hodgkin's disease	0/0.1	–	(0.00–26.62)	1/0.2	5.49	(0.14–30.57)
Non-Hodgkin's lymphoma	4/1.9	2.09	(0.57–5.35)	0/0.6	–	(0.00–6.14)
Leukaemia and aleukaemia	1/1.7	0.60	(0.02–3.34)	0/0.8	–	(0.00–4.71)
Multiple myeloma	2/1.0	2.10	(0.26–7.60)	0/0.3	–	(0.00–14.44)
Diabetes mellitus	4/4.3	0.93	(0.25–2.39)	1/1.2	0.85	(0.02–4.74)
Cerebrovascular disease	11/13.1	0.84	(0.42–1.50)	6/4.8	1.26	(0.46–2.75)
All heart disease	53/55.7	0.95	(0.71–1.25)	29/24.6	1.18	(0.79–1.69)
Ischaemic heart disease	49/47.5	1.03	(0.76–1.36)	26/21.5	1.21	(0.79–1.77)
Non-malignant respiratory disease	10/15.2	0.66	(0.32–1.21)	4/5.1	0.78	(0.21–2.00)
Bronchitis	2/3.9	0.52	(0.06–1.87)	0/1.4	–	(0.00–2.71)
Emphysema	1/1.4	0.72	(0.02–4.03)	1/0.5	2.00	(0.05–11.16)
Asthma	2/0.9	2.20	(0.27–7.94)	2/0.9	2.14	(0.26–7.72)
Cirrhosis of liver	1/1.3	0.80	(0.02–4.43)	3/0.8	3.65	(0.75–10.66)
Nephritis and nephrosis	3/1.4	2.11	(0.44–6.17)	0/0.4	–	(0.00–9.47)
All external causes of death	11/10.0	1.10	(0.55–1.96)	10/15.0	0.67	(0.32–1.23)
Accidents	10/6.2	1.62	(0.77–2.97)	7/10.6	0.66	(0.27–1.37)
Motor vehicle accidents	6/3.0	1.98	(0.73–4.30)	4/6.2	0.65	(0.18–1.66)
Suicides	1/3.3	0.30	(0.01–1.69)	2/3.7	0.54	(0.07–1.96)

Obs/exp, observed/expected.

* $P < 0.05$.

Zealand. We verified that at least 9% of our workers emigrated during the study period. The true emigration rate is likely to have been >9% since we only counted emigrants we could locate. Since emigrants do not contribute to the

national mortality rates, their withdrawal from follow-up does not introduce a bias into risk estimation. The true number lost to follow-up of no more than 236 (or 13% of the cohort), and likely to be much less, is consistent with

Table 4. SMR and 95% CI by date of hire

Cause of death	Date of hire					
	Pre-1976			Post-1975		
	Obs/exp	SMR	95% CI	Obs/exp	SMR	95% CI
All causes of death	221/219.0	1.01	(0.88–1.15)	26/35.4	0.74	(0.48–1.08)
All malignant neoplasms	69/63.9	1.08	(0.84–1.37)	7/11.2	0.62	(0.25–1.28)
Cancer of buccal cavity and pharynx	3/1.3	2.38	(0.49–6.97)	0/0.2	–	(0.00–16.55)
Cancer of digestive organs and peritoneum	25/19.6	1.28	(0.83–1.89)	2/3.2	0.62	(0.08–2.25)
Cancer of oesophagus	5/1.8	2.77	(0.90–6.46)	0/0.3	–	(0.00–14.21)
Cancer of stomach	6/3.2	1.87	(0.69–4.08)	0/0.5	–	(0.00–7.75)
Cancer of large intestine	2/5.9	0.34	(0.04–1.22)	1/1.0	1.00	(0.03–5.58)
Cancer of rectum	7/3.4	2.06	(0.83–4.24)	1/0.5	1.88	(0.05–10.45)
Cancer of biliary passages and liver primary	2/1.6	1.28	(0.16–4.63)	0/0.3	–	(0.00–11.62)
Cancer of pancreas	3/2.6	1.15	(0.24–3.35)	0/0.4	–	(0.00–9.09)
Cancer of respiratory system	16/16.1	1.00	(0.57–1.62)	2/2.3	0.88	(0.11–3.19)
Cancer of larynx	2/0.4	4.45	(0.54–16.06)	0/0.1	–	(0.00–69.99)
Cancer of bronchus, trachea and lung	13/15.2	0.86	(0.46–1.47)	2/2.1	0.94	(0.11–3.40)
Malignant melanoma of skin	1/2.1	0.47	(0.01–2.62)	1/0.5	1.90	(0.05–10.58)
Soft tissue sarcoma	1/0.3	3.12	(0.08–17.41)	0/0.1	–	(0.00–43.56)
Cancer of breast (female only)	2/2.5	0.81	(0.10–2.93)	0/1.0	–	(0.00–3.54)
Cancer of cervix uteri (female only)	1/0.4	2.25	(0.06–12.53)	0/0.2	–	(0.00–19.34)
Cancer of prostate (male only)	3/5.2	0.58	(0.12–1.68)	0/0.4	–	(0.00–9.36)
Cancer of kidney	3/1.5	2.05	(0.42–6.00)	0/0.3	–	(0.00–14.04)
Cancer of bladder and other urinary organs	1/1.5	0.68	(0.02–3.77)	0/0.1	–	(0.00–24.66)
Cancer of central nervous system	3/2.1	1.41	(0.29–4.11)	1/0.5	1.84	(0.05–10.24)
Cancer of all lymphatic, haematopoietic tissue	7/5.5	1.27	(0.51–2.62)	1/1.1	0.92	(0.02–5.14)
Hodgkin's disease	1/0.3	3.76	(0.09–20.95)	0/0.1	–	(0.00–67.24)
Non-Hodgkin's lymphoma	3/2.1	1.44	(0.30–4.21)	1/0.4	2.29	(0.06–12.76)
Leukaemia and aleukaemia	1/2.0	0.49	(0.01–2.74)	0/0.4	–	(0.00–8.80)
Multiple myeloma	2/1.0	1.92	(0.23–6.93)	0/0.2	–	(0.00–22.55)
Diabetes mellitus	5/4.6	1.08	(0.35–2.51)	0/0.8	–	(0.00–4.54)
Cerebrovascular disease	13/16.2	0.80	(0.43–1.37)	4/1.7	2.39	(0.65–6.11)
All heart disease	77/72.0	1.07	(0.84–1.34)	5/8.3	0.60	(0.20–1.41)
Ischaemic heart disease	70/62.3	1.12	(0.88–1.42)	5/6.7	0.74	(0.24–1.73)
Non-malignant respiratory disease	13/18.4	0.71	(0.38–1.21)	1/1.8	0.54	(0.01–3.01)
Influenza and pneumonia	2/3.9	0.51	(0.06–1.86)	0/0.2	–	(0.00–16.12)
Bronchitis	2/4.7	0.43	(0.05–1.54)	0/0.5	–	(0.00–6.93)
Emphysema	2/1.7	1.16	(0.14–4.19)	0/0.2	–	(0.00–23.13)
Asthma	3/1.5	1.98	(0.41–5.79)	1/0.3	3.01	(0.08–16.78)
Cirrhosis of liver	2/1.8	1.13	(0.14–4.10)	0/0.2	–	(0.00–19.23)
All external causes of death	14/17.7	0.79	(0.43–1.32)	7/7.3	0.96	(0.39–1.99)
Accidents	6/6.3	0.95	(0.35–2.07)	4/2.9	1.40	(0.38–3.57)
Suicides	2/4.7	0.42	(0.05–1.53)	1/2.3	0.44	(0.01–2.45)

Obs/exp, observed/expected.

studies done in other countries. While it is possible that those lost to follow-up may have higher mortality rates than the rest of the study population, we feel that the loss is small enough to have little influence on risk estimates.

Another potential limitation of this study is size. While we have included all workers employed at this site from

1969 to near the end of 2003, there are some causes of death which we could not credibly evaluate because they are relatively rare. For example, we did observe 1 death from soft tissue sarcoma versus 0.4 expected. This cancer has been related to TCDD exposure in some studies. With the small number of observed and expected deaths

Table 5. SMR and 95% CI by sex

Cause of death	Sex					
	Male			Female		
	Obs/exp	SMR	95% CI	Obs/exp	SMR	95% CI
All causes of death	220/214.9	1.02	(0.89–1.17)	27/39.5	0.68*	(0.45–1.00)
All malignant neoplasms	68/59.6	1.14	(0.89–1.45)	8/15.5	0.52	(0.22–1.02)
Cancer of buccal cavity and pharynx	3/1.3	2.23	(0.46–6.51)	0/0.1	–	(0.00–27.63)
Cancer of digestive organs and peritoneum	25/18.9	1.32	(0.86–1.95)	2/3.9	0.52	(0.06–1.86)
Cancer of oesophagus	5/1.9	2.68	(0.87–6.26)	0/0.2	–	(0.00–18.21)
Cancer of stomach	5/3.2	1.55	(0.50–3.62)	1/0.5	2.18	(0.05–12.12)
Cancer of large intestine	3/5.4	0.56	(0.12–1.63)	0/1.5	–	(0.00–2.38)
Cancer of rectum	7/3.3	2.09	(0.84–4.31)	1/0.6	1.70	(0.04–9.45)
Cancer of biliary passages and liver primary	2/1.6	1.25	(0.15–4.52)	0/0.3	–	(0.00–13.21)
Cancer of pancreas	3/2.5	1.20	(0.25–3.52)	0/0.5	–	(0.00–6.98)
Cancer of respiratory system	16/15.9	1.00	(0.57–1.63)	2/2.4	0.84	(0.10–3.04)
Cancer of larynx	2/0.5	4.16	(0.50–15.01)	0/0.0	–	(0.00–173.85)
Cancer of bronchus, trachea and lung	13/15.0	0.87	(0.46–1.48)	2/2.3	0.87	(0.11–3.13)
Malignant melanoma of skin	2/2.2	0.91	(0.11–3.29)	0/0.5	–	(0.00–8.08)
Soft tissue sarcoma	1/0.3	3.14	(0.08–17.52)	0/0.1	–	(0.00–42.54)
Cancer of breast (female only)	1/0.0	–	–	1/3.5	0.29	(0.01–1.59)
Cancer of cervix uteri (female only)	0/0.0	–	–	1/0.6	1.57	(0.04–8.77)
Cancer of prostate (male only)	3/5.6	0.54	(0.11–1.56)	0/0.0	–	–
Cancer of kidney	3/1.5	2.01	(0.42–5.88)	0/0.2	–	(0.00–15.95)
Cancer of bladder and other urinary organs	1/1.5	0.68	(0.02–3.76)	0/0.1	–	(0.00–25.32)
Cancer of central nervous system	3/2.2	1.38	(0.28–4.02)	1/0.5	2.03	(0.05–11.30)
Cancer of all lymphatic, haematopoietic tissue	7/5.4	1.30	(0.52–2.68)	1/1.2	0.83	(0.02–4.60)
Hodgkin's disease	0/0.3	–	(0.00–13.58)	1/0.0	20.30	(0.51–113.11)
Non-Hodgkin's lymphoma	4/2.0	1.97	(0.54–5.05)	0/0.5	–	(0.00–7.56)
Leukaemia and aleukaemia	1/2.0	0.50	(0.01–2.78)	0/0.4	–	(0.00–8.22)
Multiple myeloma	2/1.0	2.02	(0.24–7.30)	0/0.2	–	(0.00–17.10)
Diabetes mellitus	5/4.4	1.13	(0.37–2.64)	0/1.0	–	(0.00–3.54)
Cerebrovascular disease	14/14.5	0.97	(0.53–1.62)	3/3.4	0.89	(0.18–2.59)
All heart disease	77/71.8	1.07	(0.85–1.34)	5/8.5	0.59	(0.19–1.37)
Ischaemic heart disease	71/62.3	1.14	(0.89–1.44)	4/6.7	0.60	(0.16–1.53)
Non-malignant respiratory disease	12/17.3	0.70	(0.36–1.21)	2/3.0	0.66	(0.08–2.40)
Influenza and pneumonia	2/3.6	0.55	(0.07–1.98)	0/0.5	–	(0.00–7.71)
Bronchitis	1/4.4	0.23	(0.01–1.26)	1/0.8	1.25	(0.03–6.94)
Emphysema	2/1.7	1.21	(0.15–4.38)	0/0.2	–	(0.00–15.86)
Asthma	3/1.4	2.17	(0.45–6.35)	1/0.5	2.15	(0.05–11.96)
Cirrhosis of liver	4/1.8	2.20	(0.60–5.63)	0/0.3	–	(0.00–14.25)
Nephritis and nephrosis	2/1.5	1.31	(0.16–4.75)	1/0.3	3.46	(0.09–19.28)
All external causes of death	18/22.3	0.81	(0.48–1.28)	3/2.7	1.11	(0.23–3.25)
Accidents	14/15.0	0.93	(0.51–1.56)	3/1.7	1.75	(0.36–5.11)
Motor vehicle accidents	9/8.1	1.12	(0.51–2.12)	1/1.1	0.89	(0.02–4.98)
Suicides	3/6.2	0.48	(0.10–1.41)	0/0.8	–	(0.00–4.74)

Obs/exp, observed/expected.

* $P < 0.05$.

from this cause in our study, it is not possible to confirm or refute an impact of workplace exposure on soft tissue sarcoma. Such an evaluation for rare causes of death will have to wait for larger studies with detailed exposure evaluations.

A previous study at this site examined mortality levels in a subset of the workers in our study who were potentially exposed to dioxins as contaminants of the 2,4,5-T production. The investigators reported that all causes mortality in production workers was not greater than

expected; however, there were more cancers than expected including a statistically significant increase in deaths from multiple myeloma (3 observed versus 0.5 expected). In contrast, we found all cancers at expected levels and 2 deaths from multiple myeloma versus 1.2 expected. While the tracing methods used and numbers lost to follow-up were similar in both the studies, the differences in cohort definitions and subgroups studied could have accounted for the differences in observed deaths.

Due to the relatively large number of potential exposures at the plant, we did not classify the cohort with respect to particular chemicals or contaminants, but looked for effects through period of hire and latency. Period of hire is useful for isolating potential occupational exposures. The bulk of employment occurred in the decade following the inception of the study and the majority of those exposed to 2,4,5 TCP and 2,4,5,-T would have been included in the pre-1976 analysis. Most carcinogens are assumed to have long latency periods and analyses by latency are useful for examining potential workplace effects. We did observe higher total cancer rates in the pre-1976 period (SMR 1.08, 95% CI 0.84–1.37) than in the post-1975 period (SMR 0.62, 95% CI 0.25–1.28). However, the rates for total cancers were lower in the longer latency period (SMR 0.96, 95% CI 0.72–1.26) than in the shorter latency period (SMR 1.14, 95% CI 0.72–1.71). We also observed four deaths from non-Hodgkin's lymphoma in this study. Three deaths of non-Hodgkin's lymphoma occurred in the pre-1976 group (SMR 1.44, 95% CI 0.30–4.21) and one death in the post-1975 group (SMR 2.29, 95% CI 0.06–12.76). All non-Hodgkin's lymphoma deaths occurred in the longer latency group (SMR 2.09, 95% CI 0.57–5.36).

As a surveillance tool, the principal objective of this analysis was to quantify the potential hazard of employment at the site rather than of any specific chemical exposures. We observed rates for all causes, all malignant neoplasms and many other causes of death to be similar to the New Zealand general population rates, but higher than expected rates were consistently observed for short-term employees.

In summary, the results of our study indicate that there is no excess mortality risk for employees who worked at the New Plymouth site. The most critical step in addressing mortality is, however, to look at specific exposures in detail which will be the subject of future studies. This report establishes the basis from which this can be done.

Key points

- Assessment of exposure to agrochemicals at this plant by duration of exposure, period of hire and latency showed that only short duration of employment (and potential exposure) was associated with increased risk of mortality.
- It is unlikely that workplace exposures influenced the mortality risk of employees at this site.
- The results of epidemiological studies which do not include specific exposure estimates must be interpreted with caution.

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Conflicts of interest

None declared.

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