MONASH University

2023 HEALTH WATCH

The 16th Report and Final Analysis

AiP
Australian Institute of Petroleum

HEALTH WATCH

The Australian Institute of Petroleum Health Surveillance Program

Sixteenth Report

August 2023

Monash University
Monash Centre for Occupational and Environmental Health
School of Public Health and Preventive Medicine

This Sixteenth Report contains an analysis of deaths occurring up to 30th November 2020, and cancers registered up to 31st December 2016.

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MESSAGE FROM THE CEO OF THE AUSTRALIAN INSTITUTE OF PETROLEUM

Since 1980, the Australian Institute of Petroleum (AIP) has sponsored the independent *Health Watch* Study to monitor the health of petroleum industry employees in Australia, as part of the industry's very longstanding commitment to employee health and wellbeing. This internationally recognised research covers over 20,000 past and present employees during their time in the industry and after they leave or retire to examine what happens to their health. *Health Watch* is a detailed epidemiological analysis of job types, workplace practices, lifestyle influences, and illness and causes of death – comparing the health of industry employees with the overall Australian community.

The Study provides valuable insights into the influences on employee health, including the relationship between the incidence of various cancers and working in the industry, and the measurable effects of an employee's lifestyle. The Study's findings therefore assist the industry to develop workplace health policies and programs whilst also providing a robust scientific basis for community understanding of the health impacts of petroleum exposures.

Since 2005, the *Health Watch* has been conducted by the Monash Centre for Occupational and Environmental Health (MonCOEH) at Monash University, to take advantage of other health and epidemiology research. The Study has been under the direction of Emeritus Professor Malcolm Sim AM and his highly respected research team, including Professor Karen Walker-Bone, Professor Deborah Glass, Elisa Wood, and Anthony Del Monaco.

AIP welcomes the very encouraging results of the 16th Report and the final analysis after more than 40 years of continuous investigation. It continues to clearly show that petroleum industry employees have better health than the general Australian community and are less likely to die from cancer and from heart, respiratory and digestive diseases.

Most encouraging in this final analysis is the significantly reduced risk of leukaemia, including lower rates for industry employees than nationally for all leukaemia subgroups. The Study has also continued to show that the chances of dying or of getting cancer or heart disease are very similar no matter where *Health Watch* members worked, including upstream production sites and downstream refineries, terminals, and distribution sites. There is also no evidence of increased mortality or cancer incidence the longer employees worked in the industry.

The longstanding and independent conduct of the Study provides confidence in its clear published analysis and findings over the extensive study period. However, little in the way of major change in results since the last report means *Health Watch* is no longer providing new scientific information for the industry and its employees and is therefore closing.

AIP thanks the thousands of employees who voluntarily participated in *Health Watch* for decades. This has enhanced scientific, workplace and community understanding and helped to provide healthier and safer working environments for future industry employees.

Paul Barrett
CEO

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AUSTRALIAN INSTITUTE OF PETROLEUM

COMPANIES WITH EMPLOYEES PARTICIPATING IN *HEALTH WATCH*

Viva Energy Australia Pty Ltd
Caltex Oil Australia (incorporating Total, Ampol Australia and Australian Petroleum Pty Ltd)
BP Australia Pty Ltd (incorporating Amoco)
ExxonMobil Australia Ltd (formerly Esso Australia Ltd and Mobil Oil Australia Limited)
Santos Ltd
Shell Australia Pty Ltd
Chevron Australia (formerly West Australian Petroleum Pty Ltd (WAPET))
Woodside Energy Ltd
Airport Fuel Services
Castrol Australia Pty Ltd (up to 30/06/1994)

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We are indebted to the contact persons in each of the participating companies. *Health Watch* is dependent on them for follow-up information.

We thank the Australian Institute of Health and Welfare for its ongoing co-operation which has made it possible for *Health Watch* to report on the occurrence of cancer and mortality.

We also thank the staff of State Death and Cancer Registries for confirmation of information, in particular the staff of the Victorian Cancer Registry for their co-operation in searching their registry.

Finally, we wish to thank the many employees who participated and assisted the team.

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PREFACE

Health Watch is an epidemiological health surveillance program initiated by the Australian Institute of Petroleum. Since 2005, the study has been carried out by researchers from Monash University.

The *Health Watch* study encompasses a long-term prospective epidemiological study of death and cancer occurrence and a case-control study examining the relationship between leukemia and benzene exposure. The University of Melbourne oversaw the study of overall mortality and cancer incidence from 1980 to 1998, while the University of Adelaide continued the study until 2005, when it was transferred to Monash University. In 1999, researchers from Monash and Deakin Universities assumed control of the leukaemia and benzene nested case-control study. In 2006, the data collected by *Health Watch* was combined with similar studies conducted in Canada and the UK to perform a comprehensive analysis of the connection between benzene exposure and cancer risk.

Health Watch is designed to monitor the health of petroleum industry employees from all major participating oil and gas companies across Australia who voluntarily joined the program at their workplace. Nearly 95% of the employees approached from refineries, production sites, distribution terminals, and gas plants (onshore and offshore) participated in *Health Watch* during recruitment drives between 1981 and 2000. Participants were enrolled in the study by taking part in at least one of four industry surveys conducted in the 1980s and 1990s, which included a comprehensive job and health questionnaire. This questionnaire gathered information on job responsibilities, lifestyle habits like smoking and alcohol consumption, and overall health status. Employees who were interviewed were eligible to be included in the analysis after having worked in the industry for at least five years, and they remained in the *Health Watch* cohort for the rest of their lives. All participants, including current and former employees of participating companies, are regularly contacted to update their health status and employment history. A new cohort was initiated in 2010, and current employees of participating companies were invited to participate via either a researcher-assisted or an online survey.

The participating companies provide employee updates to *Health Watch* including updates on job transitions, departures, and retirements. The study has stayed in touch with cohort members until their death through regular Health Letter updates. The study's main output is a report that provides analyses of mortality and cancer occurrence. These analyses are performed by comparing the death and cancer rates of the *Health Watch* cohort to those of the general Australian population.

Deaths and cancers in the *Health Watch* cohort are determined by linking the *Health Watch* data from the State and National Death and Cancer Registries through the Australian Institute of Health and Welfare (AIHW). The Victorian Cancer Registry provide cancer registrations for that state. The number of deaths and cancer diagnoses in the general population is obtained from the AIHW, which compiles the National Death Index (NDI) and the Australian Cancer Database (ACD) for all State Death and Cancer Registries.

The results of the cohort and case-control study have been disseminated through periodic *Health Watch* reports, of which, this is the sixteenth and final report. Results have also been published in scientific medical journals and other scientific publications.(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27).

This Report is published on the Australian Institute of Petroleum website (www.aip.com.au) and the MonCOEH website (www.coeh.monash.org/healthwatch.html). Summary reports are distributed to all members of the *Health Watch* cohort.

SUMMARY OF LATEST *HEALTH WATCH* RESULTS

Overview

The *Health Watch* study continues to show that petroleum industry employees are healthier than the general Australian population and are less likely to die from leading causes of death, including cancer, heart disease, and respiratory conditions. For men, the death rates for most major disease categories were significantly lower than for the general Australian population. A significant reduction in all-cause mortality was observed among men in all workplace types, such as refineries, terminals, and upstream. For both men and women in the industry, the risk of getting cancer was comparable to that of the general Australian population. Male *Health Watch* members had a reduced mortality rate from cancer, while the cancer mortality rate for female members was similar to the expected rate.

The study did not find any relationship between increasing duration of employment and increasing mortality, cancer risk, or cancer mortality. Overall, the risk of death at any age was consistent regardless of the workplace and was lower compared to the rates among Australian men. Drivers had a slightly higher risk of getting cancer but their risk of dying from cancer was comparable to the general population risk.

Status of the cohort

This update of the *Health Watch* cohort was based on national mortality data to 30th November 2020 and cancer incidence data to 31st December 2016. 16,666 men and 1,374 women were included in the analyses in this report. 4,522 men and 142 women in the cohort had died by the end of 2020. Members who died overseas or whose deaths were not identified on the NDI could not be included in these analyses. *Health Watch* has now accumulated 506,877 person-years of observation in men and 38,746 person-years in women.

Healthy worker effect continues for men and women

The age-adjusted death rate among both male and female participants in *Health Watch* continues to be lower than that of the general Australian population, as seen in previous reports. The phenomenon known as the "healthy worker effect" remains evident. The risk of developing cancer for people in the petroleum industry is similar to that of the general population, but mortality from cancer, particularly among men, is significantly reduced among *Health Watch* members.

Results in women

Of the 142 female cohort members who have died, there were 66 deaths from cancer. The risk for women of dying from cancer was similar to that of the general Australian female population. There were 196 diagnosed cancers in women, where just over 195 were expected, i.e., the chance of getting cancer was similar for women working in this industry as it was for the general female population. The number of women in the *Health Watch* program is very small, however, and this precludes more detailed analysis of their health outcomes.

Results in men

For men, 4,522 members of the cohort have died including 1,841 deaths from cancer. However, death rates in most major disease categories - cancer, metabolic, mental,

circulatory, respiratory, digestive, urinary, and external causes (accidents, violence etc) were significantly lower than for the corresponding Australian population. The death rate for nervous system diseases was similar to the corresponding Australian population. A significant reduction in all-cause mortality was seen among men in all workplace types e.g. refinery, terminal and upstream.

Twelve cohort members have died from asbestosis (SMR 1.68, 95% C.I. 0.87-2.94) which was one more than in the previous analysis. This is probably an underestimate of the true number with asbestos related illnesses not resulting in death because not all members self-report their illnesses and there is no national register for asbestosis as there is for cancer.

Within the cohort, there was evidence of a trend of increasing overall mortality and cancer incidence by period of first employment (comparing those employed pre and post 1985), however, the mortality in these time periods was lower than the national rates for those corresponding time periods.

There was evidence of decreasing mortality risk by duration of employment but not for time since first employed (compared with those under 10 years). There was no evidence of increasing cancer or cancer mortality risk by duration of employment or time since first employment (compared with those under 10 years).

Specific cancers

Three specific cancers, mesothelioma, melanoma, and prostate cancer continued to occur at statistically significantly higher rates in men working in the industry compared with the general population.

Sixty-three mesotheliomas are included in this analysis (SIR 1.59, 95% C.I. 1.22-2.04). The risk is similar to that identified in the previous report.(28)

There was a statistically significant increase in the incidence of melanoma in men compared to the general population of Australia. The rates were significantly higher in NSW and Queensland, but when compared with state-based rates, Victoria was also somewhat elevated. The melanoma rate did not increase with increasing duration of employment, in fact, the rate decreased with increasing duration, except for those employed for 25 years or more (compared to those employed 5-9 years). While melanoma risk is known to be associated with sun exposure and many jobs in the petroleum industry involve outside work, the finding of lower risk with increasing length of employment in the industry suggests that other factors may be playing a role in this increased risk.

Although an increased risk of bladder cancer in the overall cohort was reported in previous *Health Watch* reports (4, 29), this updated analysis showed there was no longer additional risk of bladder cancer in the cohort compared to the general population. This finding was consistent with what was also observed in the 14th and 15th *Health Watch* reports. Bladder cancer risk in drivers, whilst steadily decreasing, remained elevated compared to the general population (SIR 1.29, 95% C.I. 0.83-1.90). When compared to office-only workers in the cohort, the risk of bladder cancer is no longer significantly greater in drivers in comparison (RIR 1.49, 95% C.I. 0.81-2.74). The 14th *Health Watch* report showed a borderline elevated risk of bladder cancer among drivers (RIR 1.60, 95% C.I. 0.96-2.49) and a significantly increased risk was seen in the 15th *Health Watch* Report (RIR 3.30, 95% C.I. 1.45-7.07).(23, 28)

Since the last report, there have been 24 new cases of leukaemia among men in the cohort. However, as identified in the last three consecutive *Health Watch* reports, and contrary to findings in earlier *Health Watch* reports (4, 5, 29, 30) there is now no increased risk of leukaemia. In fact, the risk of leukaemia was now significantly lower in the cohort compared with the Australian population, (SIR 0.77, 95% C.I. 0.62-0.94).

Job group analyses

Health Watch examined risk for members in some specific occupational groups, and a small overall excess in cancer incidence remains for Tanker Drivers (SIR 1.11, 95% C.I. 1.03-1.19). A similar excess was also observed in the 14th and 15th reports.(23, 28) The breakdown of major cancer categories among drivers showed that melanoma and prostate cancer were the two specific cancer types that were statistically significantly elevated compared to the general population. Oesophageal cancer risk remains elevated but is not statistically significantly increased (SIR 1.60, C.I. 0.91-2.60). The risk of kidney cancer has increased slightly since the previous reports, however, it is still not a statistically significant increase (SIR 1.40, C.I. 0.92-2.05).(23, 28)

Cancer mortality rates, however, were similar to the general population for most occupational groups, including drivers in the current analysis. Office workers had a significantly reduced risk of cancer mortality compared with the general population (SMR 0.84, 95% C.I. 0.77-0.91).

Lifestyle factors

Smoking related diseases i.e., lung cancer, cancer of the lip, oral cavity and pharynx, ischaemic heart disease mortality and chronic obstructive pulmonary disease mortality continue to remain lower in *Health Watch* members compared with the general population. However, within the cohort, there was a clear pattern that higher levels of cigarette smoking were associated with an increasing risk of all-cause mortality specifically of: ischaemic heart disease mortality; overall cancer risk; cancer mortality; and increased incidence of lung cancer and bladder cancer. Furthermore, it was clear that the risk of mortality and cancer were greatly reduced for ex-smokers compared with those who continued to smoke, however, the risk was still higher compared to those who have never smoked.

Moderate drinkers (1-7 drinks per week) had a lower death rate than total abstainers. Heavy drinking (more than 3 drinks per day) was associated with increased overall cancer and mortality risks.

1. INTRODUCTION

1.1. Industry Background

The petroleum industry was established in Australia in the early 1900s when international companies started importing fuels and lubricants. Refineries were built from 1910 and nationwide distribution networks were established. Considerable cooperation between companies enabled them to service the scattered population despite the vast distances involved. After World War II, the Australian population rapidly expanded, and this led to the development of more refineries and petrochemical plants. By the 1950s there were major refineries in three states. The technology in the industry has continued to evolve, with Australian refineries being technologically advanced but with small capacities. The country has stringent environmental legislation and emission controls, leading to advancements such as the introduction of bottom loading for tankers and hydrocarbon vapor recovery systems.

The petroleum industry in Australia experienced significant growth in the 1970s, leading to the country becoming a net energy exporter through the production of light crude oil and natural gas. In the 1990s, the industry underwent a significant restructuring, resulting in decreased employment within the petroleum companies, particularly in the refining sector. The shift towards a more contractor-based approach in refinery operations also made the industry less labour-intensive.

The downstream petroleum industry is represented by the Australian Institute of Petroleum (AIP) which was founded in 1975. AIP established a Health Committee in the same year.

1.2. Development and Design of the Health Watch Surveillance Program

In 1980, the AIP commissioned the Department of Community Medicine at the University of Melbourne to launch a health monitoring program, known as *Health Watch*, to track the key health outcomes of employees in the industry. The program has been in operation ever since, monitoring mortality and cancer cases among those who have worked or are currently working in the petroleum industry. As the industry grew, new companies and projects joined the program. The original cohort was closed to new members in 2000, but a new cohort consisting of both current and new employees was established in 2010.

What is a cohort?

The term "cohort" is used in research and statistical analysis to describe a group of individuals who are studied over a specific time period.

The Health Watch cohort is made up of people who are or have been working in the petroleum industry.

Cancer is a significant health concern in the petroleum industry, particularly for workers who are exposed to certain chemicals and substances during their work. According to a report by the American Cancer Society, exposure to certain chemicals found in petroleum products can increase the risk of developing cancer, particularly lung, bladder, and skin cancer. These chemicals include benzene, toluene, and xylene, which are commonly found in the production and transportation of petroleum products. (31)

A systematic review published in the Journal of Occupational and Environmental Medicine found that workers in the oil and gas extraction industry had a higher risk of developing certain types of cancer, including mesothelioma, melanoma, multiple myeloma, bladder and prostate cancer. (32)

In 1987, an overall excess of lympho-haematopoietic (LH) cancers (all leukaemias, multiple myeloma and all lymphomas except Hodgkin disease) was observed in the *Health Watch* cohort. To evaluate the relationship between workplace exposures (specifically benzene) and the excess of these cancers, a nested case-control study commenced within the cohort in 1988.

In 1999, the University of Melbourne relinquished responsibility for *Health Watch*, and the AIP contracted the University of Adelaide to continue the cohort study. Responsibility for the case-control study was passed to a consortium at Monash University and Deakin University. With the approval of the University of Adelaide's Ethics Committee, data required for the case-control study was provided to the consortium.

In 2005 the AIP transferred custodianship of the *Health Watch* cohort to Monash University's Centre for Occupational and Environmental Health (MonCOEH) in the Department of Epidemiology and Preventive Medicine (now the School of Public Health and Preventive Medicine (SPHPM)). With the consent of the University of Adelaide's Ethics Committee, Monash University's Ethics Committee and of the State and Territory Cancer Registries and the Australian Institute of Health and Welfare (AIHW), the cohort data were transferred to Monash University.

Although all the major petroleum companies of the AIP joined the *Health Watch* program, participation by individual employees was voluntary. The health outcomes monitored are deaths from any cause and the incidence of cancer. These measures have provided a broad view of the health experience of people working in the participating companies over recent decades. National Death and Cancer Registry data became available from 1982, which has allowed mortality and cancer incidence to be monitored and compared.

Figure 1 is a representation of the *Health Watch* cohort structure as at 30/11/2020.

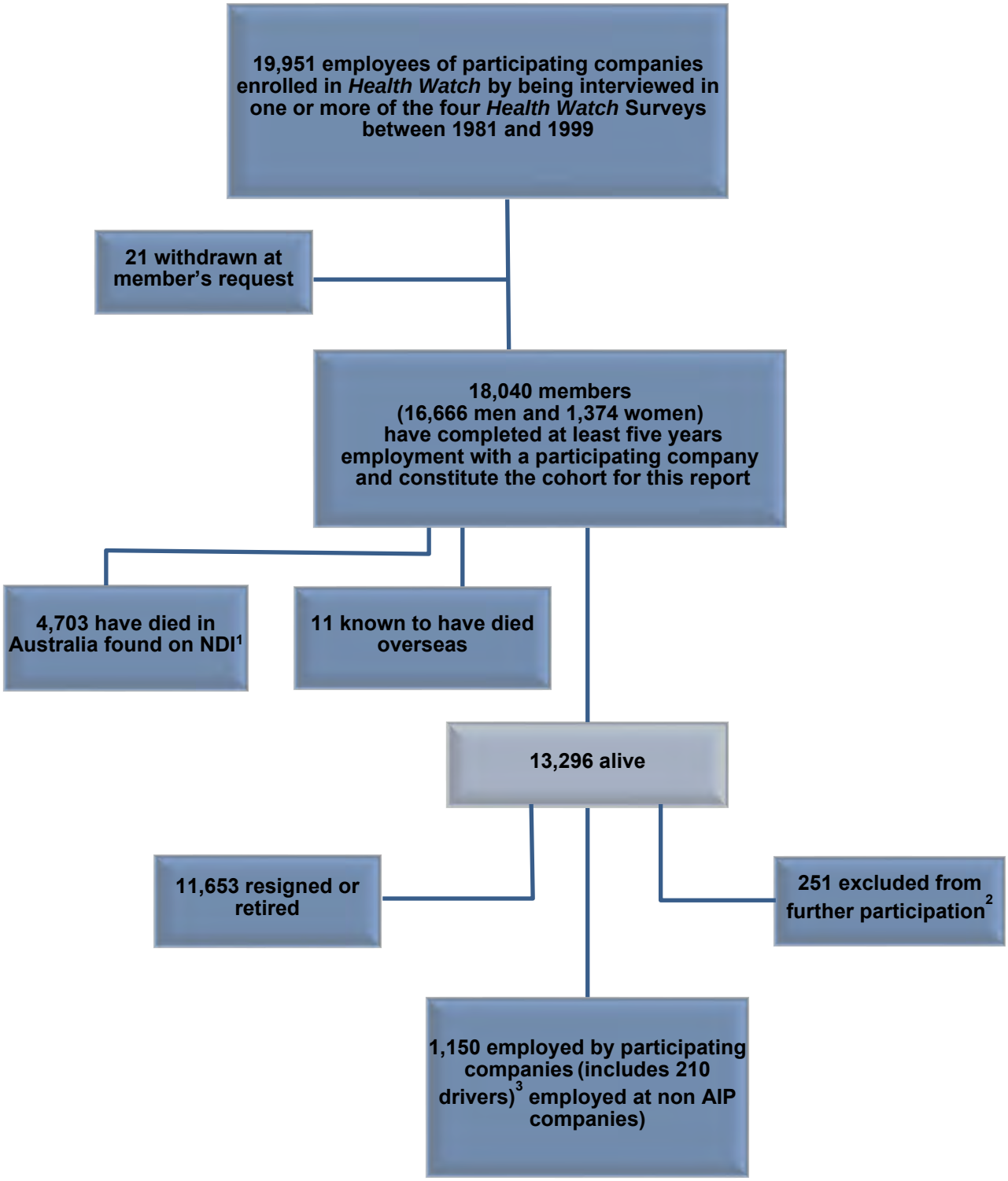

Figure 1: *Health Watch* cohort structure

1. Includes deaths from Castrol employees, however Castrol deaths after 1994 are not included in this analysis
2. Excluded Castrol employees from 1994
3. Section 2.2.8, page 26

1.3. Reporting Results

The outcomes of the *Health Watch* study are shared with the *Health Watch* Advisory Committee comprising:

- a representative of the CEO of the AIP
- representatives of petroleum companies participating in *Health Watch*
- a representative of trade unions in the industry
- representatives from the research team at Monash University.

The results are made available to *Health Watch* employees in the form of easy-to-understand summary leaflets. The project team prepares the leaflets and ensures they are distributed to current and former employees for whom addresses are available.
Results of this research program have been published in medical and other scientific journals. (1, 2, 6, 8, 11, 13, 14, 15, 16, 17, 18, 19, 20, 22, 24, 25, 26, 27)

1.4. Consent and Confidentiality

The data collected for the *Health Watch* study is stored at Monash University, following strict confidentiality guidelines and access is limited to only the study team members who have signed formal confidentiality agreements. Information that can identify an individual participant is never released, and the research adheres to the standards outlined in the SPHPM's A Guide to Good Research Practice.(33) Under the terms of the contract between the AIP and Monash University, all members of the team are bound by formal confidentiality agreements.

The *Health Watch* study protocol was approved by the Advisory Committee and all Ethics Committees and the project team is conscious of the need to avoid distress to participants and their families. Confidential medical information is managed by the Study Director, a medical practitioner, within the project.

Health Watch collected information from the cohort members, their next-of-kin, relatives, employers, and the AIHW, which maintains the National Death Index (NDI) and the Australian Cancer Database (ACD) in collaboration with state cancer registries, and the Victorian Cancer Registry (VCR).

Members of the *Health Watch* cohort provided signed consent to link their personal data to data from the cancer registries and to obtain job histories from their employers. The consent was obtained during the initial interview and was updated during subsequent surveys. Information on the consent process and its consequences were presented to prospective participants during on-site briefing sessions, in writing, and at the time of their interview. A small number of employees declined to give consent for their details to be linked to the ACD, but they remain part of the cohort, however their information is not included in the Cancer Registry searches.

Participants were only asked to consent to linkage after a pilot study and approximately 900 pilot study members in Victoria did not take part in subsequent surveys and therefore were not asked for permission to use their names for cancer registry searches. Almost all *Health Watch* participants who were asked for consent approved the linking. With the agreement of the *Health Watch* Advisory Committee, and the relevant Ethics Committees, the Victorian Cancer Registry (VCR) has agreed to match these cohort members.

1.5. Ethics Committee Approval

The *Health Watch* program deals with matters relating to medical and human research ethics, informed consent, and confidentiality. The *Health Watch* cohort study has received approval from the Monash University Human Research Ethics Committee (MUHREC).

In order to obtain identifiable death and cancer records, approval is also required from the Human Research Ethics Committee (HREC) of the AIHW, and from each of the individual state and territory cancer registry HRECs and for some states and territories, the Chief Health Officers, Data Custodians or Health Department Privacy Committees. Despite the growing complexity of the ethics approval process, approvals from all relevant departments have been obtained. Considerable time has been spent applying and reapplying for the various approvals, providing annual updates, and responding to the ethics and privacy committees of state and national data repositories, each with their own forms, procedures and timelines.

1.6. Present Work

This report is based on the work carried out in the *Health Watch* program in the period from 2017 being the 15th Report. The deaths occurring in the cohort prior to the cut-off date of 30th November 2020 have been ascertained as far as possible, and cohort mortality rates were compared with expected rates. This was the latest date for which complete mortality data was available from the AIHW. Registration of all cancers takes longer than death registrations, so that at the time of analysis, national cancer rates were only available for comparison up to 31st December 2016 for all jurisdictions. This extends the previous report by five years in respect of mortality and four years for cancer incidence data.

Mortality data are provided to the AIHW by the Registries of Births, Deaths and Marriages (BDM) and the Australian Bureau of Statistics (ABS). These data are maintained at the AIHW in the NDI. Cancer data is provided by the individual state and cancer registries to the AIHW and held in the Australian Cancer Database (ACD).

2. METHODS

2.1. Study Design

The overall design of the *Health Watch* program is that of a prospective cohort study and the cohort structure has recently been described elsewhere. (26)

Within the cohort, a case-control study was conducted examining the association between benzene exposure and certain cancers of the blood, bone marrow and lymphatic systems known as lymphohaematopoietic cancers (LH cancers). In the past, benzene exposure of cohort members with these cancers was estimated and compared with the estimated exposure of a sample of cohort members who did not have these cancers. The comparison enabled an estimation to be made of any association between these cancers and exposure to benzene. This aspect of the study was started at Melbourne University and completed by a consortium from Monash and Deakin Universities, concluding in 2001. The outcome of the study and the methodology were reported to the AIP in 2001 (12), and in peer reviewed literature.(10, 11, 12, 13, 15, 16, 17, 18) The complete report can be accessed on the AIP website (www.aip.com.au).

The case-control study was updated in a collaborative study with cases from two similar overseas petroleum industry cohorts in 2012. These are the UK Institute of Petroleum study and the Canadian Imperial Oil study.(34, 35) The combined case-control study was funded by the Conservation of Clean Air and Water in Europe (CONCAWE). This is the Health, Safety and Environment Office of the European Petroleum Industry, a European refining industry body. Funding was also provided by the American Petroleum Institute, the Aromatic Producers Association, the Institute of Petroleum; and the Canadian Petroleum Products Institute. The methodology and findings have been published elsewhere. (20, 21, 22, 24, 25, 27)

2.2. Formation and Maintenance of the Cohort

2.2.1. Recruitment

The following section focuses on the recruitment process for the original *Health Watch* cohort.

The existing *Health Watch* cohort was established through participant recruitment by interview in four consecutive surveys. In 2010-2012, a new cohort known as the Re-opened cohort was also established through a recruitment effort. A total of 1,041 existing cohort members also took part in the Re-opened cohort. This new cohort is treated as a separate entity and is discussed in Section 9.

All employees of participating petroleum companies operating in Australia, who worked in refineries, storage and distribution terminals, offshore and onshore production facilities and airports were eligible to become members of the *Health Watch* cohort. Employees working in capital city offices and sites with fewer than ten employees were excluded.

Altogether, four surveys were carried out before the cohort was closed to further entry in 2000. The First *Health Watch* Survey was carried out in 1981-83. The Second *Health Watch* Survey was in 1986-87, the Third *Health Watch* Survey was conducted during 1991-93 and the Fourth *Health Watch* Survey was undertaken between 1996 and 2000. The repeated surveys allowed updating of information for cohort members who were still employed, and

the recruitment into the cohort of new employees who had joined the industry since the last survey.

Site rolls were provided by the participating companies, and these were used to contact each employee to offer them the opportunity to participate in the *Health Watch* study. During the periodic surveys, an employee voluntarily attended an on-site interview with a project team interviewer. Full and informed consent procedures were undertaken for each employee during pre-interview briefings to employees in groups and individually at the time of interview. The major purpose of these briefings was to explain the nature of the study, the implications of entry and the consent procedures, and to provide feedback to existing and prospective cohort participants.

For each survey, interviewers were trained in the application of the questionnaire. *Health Watch* surveys have used almost identical questionnaires and the methodologies have remained comparable, although some changes in technology have occurred. Most of the Fourth Survey was conducted by the University of Melbourne using direct input to portable notebook computers. The interviewer had access to all the previous job histories of current members and could accept potential corrections to previous data. Not all sites were visited for the Fourth Survey, (offshore sites were not included), however further questionnaire responses were obtained by mail and by telephone.

2.2.2. Entry to the Cohort

Individuals became part of the *Health Watch* cohort either after finishing a survey interview or upon reaching five years of service in a participating company, whichever came last. Consequently, if a member of the study group had already achieved five years of employment at the time of their initial interview, they immediately became a member of the cohort.

2.2.3. Information Collected at Survey Interviews

Demographic information collected at interview included name, gender, date of birth and country of birth. Health information, related to current or significant past health problems, was also collected.

Employment information was obtained in some detail: members of the cohort were asked their occupation, the area they worked in, the tasks they performed, and the proportion of the working week spent in each area. During the first two surveys, details were collected by interview on the current job held by each participant. Participants were also asked to identify jobs held for up to five years prior to their first interview.

By 1990 it was apparent that more complete job histories were required for the purpose of the nested case-control study of LH cancers within the cohort. Accordingly, in 1991-93 during the Third Survey, all participants were asked at interview about all jobs held during their employment in the petroleum industry. The complete job histories were collected from nearly all current employees who participated. In a few cases where complete employment histories were not obtained, or later proved to be incomplete, the computerisation of the Fourth Survey allowed gaps in the information to be more easily identified and corrections to be made at the time of re-interview. By this time about 4,000 men and 250 women had retired or resigned from the industry after having worked for at least five years. Their

complete job histories were collected by including questions in the periodic Health Letter sent to all retirees, which was undertaken in 1994-95. Retirees were generally longer serving employees than those still employed, and therefore had longer gaps in their previously collected job histories. The response rate from retirees to requests for complete job histories was about 80%. Some job history information for deceased members was completed by surviving partners or family. Retirees are thus likely to have less accurate complete job histories than employees who were interviewed in the Third Survey. These more complete job histories were used to assess benzene exposures in the case-control study rather than the more limited information obtained from the survey.

Lifestyle information was also obtained at interview. Standard questions on present and past smoking habits were asked of each participant, and a lifetime smoking history was recorded. Information on alcohol consumption was also collected during the survey interviews. Each cohort member interviewed was asked: "In an average week, on how many days would you have a drink?" and "How many drinks would you usually have on those days?" A drink is defined as a standard measure as served in a hotel or bar. The average number of drinks taken weekly could then be estimated.

2.2.4. Information from Participating Companies

Participating companies have periodically provided lists of new employees, transfers, resignations, and retirements. Following the decision to close the cohort to further entry in 2000, companies have continued to provide lists of transfers, resignations, and retirements on request. This information from companies was used to compute the date of termination of employment of all members of the cohort and vital status for all current employees. In some cases, addresses have been provided to update the contact details used for the periodic Health Letter (Section 2.2.7, page 25).

2.2.5. Coding of Employment Data for Assigning Estimates of Hydrocarbon Exposure

A precise job description code was used as the principal exposure index for the cohort analysis, based on collection of a job history from each participant. The job classification developed for the American Petroleum Institute (API) was used, with modifications on the advice of local occupational hygienists in the Australian industry (36, 37). More details of the coding were included as Appendix 1 to the 9th *Health Watch* report.(4)

Direct measurements of exposure to hydrocarbons were generally unavailable for the several decades of interest to *Health Watch*. In the absence of such information from companies, estimates of exposure were derived from the job details provided at the survey interviews. A hydrocarbon ranking methodology was established in the early 1980s. During 1994-96 the rankings were revised to take account of changes to workplaces and exposures. The categorisation and groupings are however, out of date. For example it did not take into account the change from top loading to bottom loading of tankers which significantly reduced exposure to hydrocarbons.(11) Therefore, as agreed in a meeting of the HWAC in 2007, the overall hydrocarbon ranking has not been revised and was not used in this or the previous two reports.

A more rigorous, quantitative methodology for assessing benzene exposure was developed for the *Health Watch* case-control study. However, the assessment was applied to only the

cases and controls in the case-control and pooled studies and was not applied to the cohort as a whole.

2.2.6. Participation Rates in *Health Watch* Surveys

For the first two surveys, a record was kept of the proportion of employees interviewed. In both surveys, approximately 93% of employees on the site rolls agreed to participate. It is estimated that 84% of eligible employees were interviewed in the Third Survey.(7) In the Fourth Survey, not all worksites were visited. Further contact was made by mailing out questionnaires and by telephone, but the response rate was not as high as that obtained by on-site interview. Seventy three percent of *Health Watch* members still employed were re-interviewed in the Fourth Survey, and an additional 1,479 new employees were interviewed. A previous report identified that the incompleteness of the Fourth Survey was largely a result of lack of recruitment of offshore production workers.(7)

In 2003, a Fifth Survey was carried out by the University of Adelaide. This was a questionnaire that was sent to all members of *Health Watch* still employed by participating companies. There was a 40% response rate and more details of this are provided in the 12th Report.(7) In addition, members of *Health Watch* who were no longer employed by participating companies were sent a reply-paid questionnaire with their 2002 letter. There was a 62% response rate from these cohort members.(7)

2.2.7. Follow-up

Efforts are made to maintain contact with all *Health Watch* cohort members. Retired members are sent periodic Health Letters where they are asked to report changes of address, illnesses and changes in smoking or drinking habits. This is important when updating personal information; in particular, it is one of the main means of determining the vital status of cohort members.

A member is deemed "Lost to Contact" when reliable contact information is not readily available. If a *Health Watch* member doesn't respond to a routine Health Letter, or if it is sent back undelivered, and the employing company cannot supply a recent address and a contactable phone number is not available in the White Pages, then that individual is classified as "lost to contact." Nevertheless, the member remains a part of the cohort analysis, ie this status merely signifies the absence of a contact method.

Following an extensive search by a commercial organisation, Adelaide University located most individuals in the cohort who had been previously classified as lost to contact. Adelaide University estimated in 2003, that 4% of the cohort was lost to contact and the percentage loss of observation time from loss of contact was only 1.3% in men and 4.9% in women.(7) The Department of Immigration and Multicultural and Indigenous Affairs[1] (DIMIA) records identify individuals' last departure or arrival in Australia. For this Adelaide report, the DIMIA records provided to Adelaide University were reviewed and those people who left before 2000 and had not returned by 2003 were assumed to have emigrated.

[1] Now The Department of Immigration and Border Protection

Most recently, Monash University sent a summary of the latest findings in the 15th *Health Watch* report to all members of the cohort with a Health Letter in 2018. This was sent to the entire cohort, either to their place of employment or to a home/postal address if the employee was retired/resigned. There was no attempt to locate those members who did not respond to the 2018 Health Letter. Of the 12,806 letters sent to eligible members of the original cohort, 3,382 (26%) returned the mini survey.

It is important to clarify that a non-response does not necessarily mean a member is lost to follow-up and those identified as lost to contact still appear on the cancer and death registries. After consulting with the *Health Watch* Advisory Committee, the decision was made not to pursue another commercial search due to potential privacy law concerns.

2.2.8. The Special Case of Drivers

For some years, most participating companies have outsourced Tanker Drivers' duties to transport contractors. Many tanker drivers who formerly worked for participating companies now work for contractors but perform identical duties to those previously performed. Although the contractors are not members of the AIP, it has been possible to identify many such tanker drivers from their responses to the Health Questionnaires and Health Letters. In such cases, the drivers have been classified as still "employed" and are included in the analyses.

Other *Health Watch* members have continued to work in the petroleum industry for non-AIP member companies. They perform a variety of tasks not readily assigned to the API job coding system, so their non-AIP jobs have not been included in the duration of employment.

2.3. Withdrawal of Members of the Cohort

Up to the 15th *Health Watch* report, there have been 21 cohort members who have indicated that they wish to withdraw from the study and do not wish to participate further in *Health Watch*.(28) There have been no additional withdrawals since the last report. The follow-up time for those 21 people has been excluded retrospectively (i.e., back to their enrolment), and they have been excluded from the analyses presented here. With the permission of MUHREC, if a person asks to be withdrawn from the cohort, they are sent the necessary formal notice of withdrawal to sign and a letter explaining that withdrawal means that past contributions are deleted. They are also offered the option of remaining in the cohort, but with no further communication from *Health Watch*.

2.4. Health Outcomes

Health Watch cohort members have provided information on their health in successive *Health Watch* surveys and in questionnaires sent to members of the cohort who are no longer employed by participating companies. The only health outcomes that have been statistically analysed are cause-specific death rates and cancer incidence rates. These analyses are not based on information supplied by members of the cohort, but from the national mortality and cancer records. However, health information supplied by members of the cohort has proved useful when verifying matches with official records. For example, if there is uncertainty as to whether a name appearing in a death linkage is the same individual as a person with the

same name in the *Health Watch* cohort, identification is assisted if the person has notified *Health Watch* of a corresponding illness, or a next of kin has notified of a death.

2.4.1. Mortality Data

Examining all causes of death offers a comprehensive view of significant health trends, given their direct connection to mortality outcomes. However, *Health Watch* cannot analyse certain medical conditions like osteoarthritis, where death is not a direct result, because there is no population registry for these diseases. Conversely, conditions where a correlation exists between the number of deaths and overall illness severity, such as ischaemic heart disease (also known as coronary artery disease) can be effectively investigated using *Health Watch* data.

For the purpose of mortality analyses, death records are obtained from the NDI, maintained by the AIHW. The NDI is compiled from death records from state registries of Births, Deaths, and Marriages, and causes of death, coded by The Australian Bureau of Statistics (ABS). The International Classification of Diseases (ICD) version 9 (ICD-9) coding was used for deaths occurring up to and including 1996.(38) Deaths occurring from 1997 onwards are coded in ICD-10.(39) The categorisation of deaths according to their causes is utilised to generate yearly national statistics on cause-specific death rates (mortality rates).

Before each report, Monash sends a list of *Health Watch* members, along with their birth dates, to the AIHW. The AIHW uses a matching algorithm to identify likely and possible matches, which are then forwarded to *Health Watch* for clerical review. Determinations are made on which names from the list are to be recognised as true matches. This process can occasionally be complicated due to many older state death certificates only providing the person's age (in years) at the time of death, rather than their date of birth. Final decisions on uncertain matches may use information already held by *Health Watch*, such as notification of a death from next of kin or from companies. Previously, it was sometimes possible to obtain a copy of the death certificate, where certain items of information (e.g., occupation or place of birth) can be compared with information held by *Health Watch*. Changes to the privacy landscape have made it very difficult for anyone other than the next of kin to obtain a copy of the death certificate.

The coded deaths verified as true matches are compared to Australian mortality statistics, leading to the computation of a comparative index known as the Standardised Mortality Ratio (SMR) (Section 2.5.2, page 31). As of the time of this analysis, the NDI is considered to have a comprehensive record of all deaths and their coded causes up until November 30, 2020, which is consequently established as the cut-off date for the mortality analyses included in this report. Deaths identified from the NDI occurring after this cut-off date have not been included in the analyses.

2.4.2. Validation of Mortality Records

Mortality analysis is conducted by comparing death rates in the *Health Watch* group with expected rates. For this analysis to be credible, the datasets must be akin to each other.

Health Watch does not rely solely on NDI linkages to learn of deaths, but only uses NDI death records for analyses. Notification of deaths in currently employed members of the *Health Watch* cohort may be supplied by the employer. Deaths of members who have left the industry may be notified by next of kin in response to a mail contact or voluntarily via

the *Health Watch* freecall number or email address. About a quarter of the deaths among eligible *Health Watch* members have been notified in this manner. Most of them have been subsequently identified through the NDI search, but a small number have not. A further 11 members have died overseas. These deaths have not been included in the analyses because they do not appear on the NDI and therefore cannot be confirmed with a cause of death.

It is not possible to be certain that all deceased members of the cohort are identified in the matching process. For example, when members of the cohort have changed their name (e.g., women after marriage or divorce) it is possible that their deaths may not be detected. In addition, members who die overseas e.g. after emigration, will not appear on the NDI. Therefore, absence of a person's name from the NDI does not necessarily mean that he/she is alive. As discussed in Section 2.5.1 (page 30), the follow-up time of such members ceases from the date of emigration for those who died overseas or the cut-off date 30/11/2020.

In all previous linkages prior to the 14th *Health Watch* analysis, matches from preceding NDI searches were accepted and added to the new matches found from the additional years that were searched in the new linkage. The current linkage covers the entire follow up time of the cohort, not just the additional years of follow up since the last report. This means the entire linkage is repeated and any differences between previous linkages are cross checked to see if any matches have been missed.

Prior to the 2014 analysis, deaths were re-coded at Adelaide or Melbourne University based on individual death certificates. Some data was also coded from ICD10 back to ICD9. In some cases, these manually re-coded deaths did not match what was recorded on the NDI. For this report, only cause of death data obtained from the current NDI linkage has been used to ensure it is consistent with the national population data in these analyses.

2.4.3. Cancer Incidence

In every Australian state and territory, cancer is a reportable disease, and all cancers except non-melanoma skin cancer, are legally required to be reported. These cancers are then notified to the AIHW which complies them into the ACD which is, therefore, a complete registry of almost all cancers diagnosed since 1982. These data are used to produce national cancer incidence statistics.

The names and dates of birth of all members of the cohort (except those who did not consent to the linkage) are linked to the ACD. Further data from Victoria is directly sourced from the VCR. The uncertain but possible matches are clerically reviewed by the AIHW and VCR and only highly certain matches released to *Health Watch* because of privacy restrictions.

The analysis was carried out up until the point at which the ACD is deemed to be complete. In this report, the cut-off date is December 31, 2016, which is four years earlier than the available death data. All cancers are coded in ICD-10 and cancer cases are grouped into various categories based on the ICD-10 coding system.(39) These categories range from malignancies which include all types of cancers, to broad organ system groupings which contain a range of cancer codes, such as respiratory (C30-C38), or digestive system (C15-C25). Cancers are also categorised into more specific single site sub-categories such as stomach (C16) or bladder (C67).

Cancer incidence is reported here although mortality figures are also provided where appropriate. This is because cancer incidence is a more reliable indicator of the cancer rate than cancer mortality. Cancer death rates are influenced not just by the incidence of cancer, but also by additional factors like availability and use of screening, the availability of effective treatments, accessibility to healthcare, and the existence of concurrent health conditions. Survival rates for many types of cancer are now quite high.

2.4.4. Validation of Cancer Incidence

Only cancer matches found in the current linkage were used in this analysis. Previous matches that were not matched this time were not included, but any differences in matches between linkages were cross checked. Cancers can be re-coded by the registries to other sites over time (especially those initially coded as "unknown") and can also change between being malignant and non-malignant and vice-versa. Therefore, it is preferable to refresh the entire list of matched cancers in each linkage. This ensures that the cohort cancers can be confidently compared to cancers in the general population. It is, however, possible that numbers in each cancer category may change slightly in each analysis. The changes were small and were unlikely to alter the findings.

Current Cancer and Death Linkage and Job Groups
This report analyses deaths occurring up to 30th November 2020, and cancers registered up to 31st December 2016. The current linkage covers the entire time span of the cohort, not just the additional years of follow up since the last report. This provides an accurate account of the status of the cohort.

The job groups in this report are Drivers, Refinery operators (not including ship personnel), Terminal operators and Maintenance (refinery or terminal based not upstream) and Office workers.

2.5. *Statistical Analyses*

The analyses undertaken for this report was completed in conjunction with MonCOEH and KTZ Ventures Pty Ltd using an updated version of the SAS code developed at Adelaide University. All analyses were performed using the SAS software (version 9.4).

The basic analyses in *Health Watch* are to compare the death and cancer incidence rates of the *Health Watch* cohort with the corresponding rates in the general population by sex and by five-year age groups. The rates are expressed as the number of deaths or cancers as a proportion of the person-time of follow-up.

The total person-time is the cumulative total of the follow-up time of each individual in the cohort. For example, if 20 people are each followed up for 10 years, the total person-time would be 200 person-years. If two cancers occurred in these 10 people over that time, the cancer rate would be two per 200 person-years.

2.5.1. Follow-up Time

The definition of cohort members' follow-up time (expressed in person-years) is critical. Follow-up time commences on admission to the cohort (Section 2.2.2, page 22), which is the date of initial survey interview, or on completion of five years of employment in the industry, whichever is the later.

Follow-up time stops on the date of death or the cut-off date (30/11/2020 for mortality, 31/12/2016 for cancer) or the date of emigration, whichever occurs sooner. Members of the cohort who have emigrated cease to be followed up after leaving Australia. This is because if individuals die or are diagnosed with cancer outside Australia, their death or cancer diagnosis would not be recorded in the national death and cancer data. As these deaths or cancer diagnoses are not included in the analyses, the person's corresponding follow-up time is excluded from the denominator.

There are two categories of members of the cohort lost to contact:

(i) Those who will be found on the NDI when they die
(ii) Those who will not be found on the NDI when they die.

An individual who has lost contact with *Health Watch* may still reside in Australia and would be identified in the NDI upon their death. However, an individual who has emigrated and continues to live abroad will never be included in the NDI. Similarly, a person who has altered their name might be listed in the NDI under their new name, and a match with the NDI might never be found.

In most previous *Health Watch* reports, members of the cohort not found to be deceased or not known to have emigrated were treated as living, and all had their follow-up time extended to the cut-off date for the analyses. The inclusion of these people in this way could result in slight over-enumeration of person-years, leading to a slight underestimate of the mortality (or cancer incidence) rate relative to the expected rate. As discussed in previous *Health Watch* reports, some individual cohort participants who were previously considered to be lost to follow up have been identified in later matches with the NDI and ACD.

For this report, two new sensitivity analyses were carried out to assess the impact of potentially missing the deaths of older individuals. Firstly, by removing person-years for those members who reached 90 years of age (i.e. censoring follow-up at 90 years of age) and then a second approach of removing these members from the analyses.

For all analyses in this report the follow up date is up to:

- 30/11/2020 for mortality and 31/12/2016 for cancer
- Date of emigration
- Date of death if found on NDI
- Date of death notification if not found on NDI, but a death has been reported.

2.5.2. External Measures of Comparison: the SMR and SIR

Health Watch compares death and cancer incidence rates in the petroleum industry with the national rates to produce measures called the standardised mortality ratio (SMR) and for cancer the standardised (cancer) incidence ratio (SIR) respectively. Both SMRs and SIRs are age-standardised because death and cancer rates greatly fluctuate with age. These rates also differ based on sex, so calculations are separately done for men and women.

The SMR is a measure of the death rate occurring in the *Health Watch* cohort compared with the death rate occurring in the national population. This ratio can be measured for the whole cohort or a subset of employees, for any particular cause of death, or for all causes. The SMR tables display the number of observed deaths in the *Health Watch* population, and the estimated expected number of deaths. The expected number is computed from the expected rates (by age, sex and year of occurrence) provided by the AIHW (40) and the number of person-years spent by cohort members in each age, sex and year-of-occurrence stratum.

Comparison of the observed and expected number produces the SMR. If the deaths in the *Health Watch* cohort are occurring at the same rate as they do in the national population, then the SMR will be 1.0. If the SMR is greater than 1.0 then deaths in the cohort are occurring more frequently than would be expected if national death rates applied to the *Health Watch* population. If the SMR is less than 1.0 then deaths in the cohort are occurring less frequently than they do in the national population. Thus, the SMR forms a measure of the risk of mortality in the *Health Watch* cohort compared to the Australian population.

When measuring the risk of developing cancer, the standardised cancer incidence ratio (SIR) is calculated. The SIR is calculated in a similar way to the SMR. To calculate SIRs the expected numbers from national cancer incidence are required and these data are derived from the ACD and take into account age, sex and year of occurrence).(41)

2.5.3. Internal Measures of Comparison: the RMR and RIR

Health Watch also uses internal comparisons to look at the health effects of working in the petroleum industry. Relative risk is employed to assess whether members of a specific subgroup, such as particular job categories, have a higher or lower risk of death or cancer compared to other subgroups. In this analysis, a baseline group is selected to represent a risk of 1.0 for a particular exposure or subgroup. The risk for all other exposure groups or categories is then calculated relative to the baseline group. The measures of these

comparisons are the relative mortality ratio (RMR) when death is the outcome or relative incidence ratio (RIR) when cancer is the outcome.

When a measure or ranking of exposure is available, it becomes possible to calculate the relative risk of death or cancer by comparing individuals with lower levels of exposure to those with higher levels. In general, it is anticipated that if the exposure is indeed causing the effect, individuals with greater exposure in terms of duration or intensity would experience more pronounced health effects. This would be reflected in the health outcomes observed. This is known to apply, for example, to the number of cigarettes smoked and the risk of lung cancer.

The reference category for these analyses is usually the least exposed group. For smoking it is people who have never smoked. If the RMR or RIR for any group in *Health Watch* is 1.0 then deaths or cancers, respectively, are occurring at the same rate as they do in the reference group. In other words, there is no significant difference in mortality or incidence rates between the two groups. If the RMR or RIR is greater than 1.0 then deaths or cancers are occurring more frequently than they do in the reference group. If the RMR or RIR is less than 1.0 then deaths or cancers are occurring less frequently than they do in the reference group.

2.5.4. Confidence Intervals and Risk Estimates

The rate ratios, SMR, SIR, RMR and RIR, are accompanied by 95% confidence intervals (95% C.I.). The value assigned to the ratio is, in fact, a statistical estimate of the actual ratio and the exact value of the true ratio cannot be known with certainty. To account for this uncertainty, the range of estimates within which it is 95% certain that the true ratio falls can be calculated. This range is referred to as the confidence interval. It provides an indication of the precision and reliability of the estimated ratio.

The choice of 95% confidence intervals is commonly used in health studies, and simply means that the certainty of the result is such that the odds of the true figure lying outside the confidence interval are about 5% or 1 in 20.

The size of the group has an impact on confidence intervals. It is possible for two groups to have the same point estimate of risk, but the group with a larger sample size will typically have narrower confidence intervals. The larger the group, the more precise the estimate becomes, resulting in a reduced range of uncertainty (narrower confidence intervals) around the point estimate.

This means that larger groups, such as onshore production workers, may exhibit statistically significant outcomes. However, smaller groups, such as offshore production workers, may not demonstrate statistically significant results even with similar point estimates, as in Table 24. In addition, deaths and cancer cases accumulate in the cohort as it ages as occurs in the general population. This means that increased or decreased risk estimates may reach statistical significance over time.

2.5.5. The Problem of Multiple Analyses

The convention of 95% probability accepts that there is a 1 in 20 chance that an increased or decreased risk has happened by chance. When multiple comparisons are conducted, as is the case in this report, there is a possibility of identifying chance findings as statistically significant i.e. some results may appear significant purely by chance. This highlights the need for cautious interpretation and consideration of the overall context when assessing the significance of multiple comparisons in this and previous reports and the findings from other studies.(42, 43, 44, 45, 46) In this report the risk estimates are discussed with reference to those from previous reports, to aid interpretation.

2.5.6. Confounding Variables

Confounding variables are factors (other than those under investigation) which may affect the cohort health outcomes. Where these factors can have large influences on outcomes, such as with smoking and cancer, it is necessary to account for them in the analyses. Even small differences in exposure to tobacco smoke can cause large differences in lung cancer rates. To cause confounding, a variable must be a cause of the disease in its own right, and to be unequally distributed between the different groups being compared and not measured or are unable to be adjusted for in the analyses.

Differences in risk between various exposure groups could therefore be masked or falsely calculated if confounding variables are not allowed for.

What is a Confounder?

A confounder is a term used in epidemiological studies in which a group with a particular exposure history is compared with a group without the exposure. In such studies, the presence of a confounder can lead to a misleading result.

To cause confounding, a variable has to be a cause of the disease in its own right, and to be unequally distributed between the different groups being compared.

For example, the lung cancer rate in a group of workers exposed to a carcinogen (say asbestos) may be compared with the rate in a group of workers not exposed. Since smoking can cause lung cancer, smoking prevalence is a potential confounder in this analysis. If the group exposed to asbestos happens to have a higher proportion of smokers than the comparison group, an excess of lung cancer in the former may be incorrectly attributed to the asbestos, whereas it may be partly or wholly due to the difference in smoking. In such a case, the variable "smoking prevalence" is a confounder, where smoking rates are unknown.

2.5.7. Adjustments to SMR and SIR analyses

The SMR and SIR estimates were adjusted for age and calendar year. These variables were chosen because of their well-established association with these health outcomes. For example, in the case of calendar year, the incidence rate and mortality rates of many cancers have undergone marked changes over the period since *Health Watch* began. Confounding by sex is avoided by separate analyses of men and women.
Adjustment for tobacco smoking is more difficult. Although *Health Watch* has obtained good smoking data on members of the cohort, comparable data are not readily available for

the general population. An indirect method of estimating whether the smoking prevalence differs from the general population is to examine the cancer rate or death rate from diseases almost exclusively due to smoking, such as emphysema and laryngeal cancer.

2.5.8. Adjustments to RMR and RIR analyses

All RMR and RIR analyses were adjusted for age and calendar period of follow-up as well as smoking status. The confounding effect of smoking is more readily dealt with in RMR/RIR analyses, because unlike SMR/SIR analyses, no reference to national smoking rates is required. Direct adjustment has been made for the confounding effect of smoking in RMR and RIR analyses. For the purposes of these adjustments, smokers are categorised into two categories – *ever smoked* vs *never smoked*.

2.5.1. Analyses by Self-Reported Smoking and Drinking Status

The analysis of mortality and cancer incidence has been carried out by self-reported rates of smoking and alcohol consumption. This allows for an examination of how these lifestyle factors influence the occurrence of mortality and cancer within the *Health Watch* cohort.

2.5.2. Time-related Variables

Analyses were carried out using three time-related variables which assist in examining any occupational cause for excess death rates or cancer rates. These were:

- period of first employment in the industry
- duration of employment in the industry
- time from first employment in the industry.

Period of first employment analyses may provide evidence as to whether exposures in particular calendar periods may have had risks attached to them. Because technology and work procedures, and therefore exposures, have changed over the past decades and over the follow up time of the cohort, health outcomes must be explored to ascertain whether they are related to historical exposures or reflect current risks. If hazardous exposures were present in higher concentrations in the 1970s than in the 1990s, and if some cancer types occurred at a higher rate in the former period, it could be inferred that the exposure may be associated with that type of cancer.

The analyses by duration of employment in the industry help to investigate whether an excess death or cancer rate may be work-related, even though the specific causal agent in the workplace is not known. The total or cumulative exposure will increase with increasing duration of employment. Therefore, if the workforce is divided into different categories according to duration of employment, and the death or disease rate increases with increasing employment duration it is likely to be related to an exposure at work. In cases where an individual temporarily leaves and subsequently returns to work with a participating company, the duration of their absence is subtracted from the total time considered for these analyses. This adjustment ensures that the period of absence is accounted for in calculating the overall duration of employment.

Examining the elapsed time from initial employment to the diagnosis of cancer or death attempts to investigate potential latency periods associated with the onset of diseases, particularly cancer. These analyses provide valuable information on disease latency and

potential relationships with occupational exposures. Employment here refers to employment with one of the participating companies (or a contracting company in the case of tanker drivers who were formerly employed by a participating AIP company). The date of commencement was obtained from members of the cohort in the survey interviews. Termination dates are obtained from companies. Duration of employment should not be confused with follow-up time, which continues after members of the cohort cease working for participating companies.

2.5.3. Analysis by Workplace Type

Separate analyses have been performed on different categories of workplace. There are five types of workplaces in this report: Refinery, Terminal, Airport, Onshore production and Offshore production. Where a participant has worked in more than one workplace type, he or she is assigned to the workplace worked most recently.

2.5.4. Analysis by Job Type

Analysis of health outcomes for specific categories of job (single Job code) is dependent on there being sufficient members of the cohort who carry out this particular job. The largest groups of employees in the industry are driver, refinery operator, terminal operator, maintenance (terminal and refinery combined) and office (clerical and managerial) and shift worker. The latter three categories are composite groups brought together to allow for job type analyses and have been used in previous *Health Watch* reports. Upstream workers are a smaller group and are not divided into specific jobs but examined as a group by workplace type.

The job groups formed from the API job codes were revised in the 14th *Health Watch* report mainly to remove overlaps and ships' personnel. The revised job groups are also used in this report except for shift workers. The classification of shift workers was based on self-assessment responses obtained from the questionnaires. Employees belonging to the shift worker category are also included in other job groups, such as operators and maintenance workers. This category has again been removed from these analyses due to the lack of consistency between jobs and companies. Accordingly, except for drivers, whose coding has not changed, it is not appropriate to make direct comparisons between the risks for these job groups in this report and the groups in reports prior to the 14th *Health Watch* report. The API job codes grouped in this report are:

- *Drivers* (NB295x)
- *Refinery operators* (not including ship personnel) (BA, BB, BC, HX, IB, PA, PB, PC, RF)
- *Terminal operators* (BA, BB, BC, HX, IB, NA, PA, PC, RF)
- *Maintenance* (refinery or terminal based not upstream) (IB, CA, CB, CC, CD, CE, CF, DA, DB, DC, DD, EA, EB, EC, FA, FB, GX, MX)
- *Office workers* (AX)

3. GENERAL RESULTS FOR THE COHORT

Results are reported for cause of death (mortality) and cancer incidence, for men and women in the cohort. Because of the small number of women, analyses cannot be carried out at the same level of detail as for men.

All statistically significant values are highlighted in bold text throughout the tables. When cancer or mortality counts are less than six, the observed and expected numbers are not reported. This is to keep in line with confidentiality practices and reducing the risk for potentially identifying a cohort member.

3.1. The Cohort Population

3.1.1. Description of Cohort Population on 30th November 2015

The current analyses include a total of 16,666 men and 1,374 women from the *Health Watch* cohort who meet the eligibility criteria for this study. These numbers reflect the preponderance of men employed in the industry.

Table 1 details the distribution of year of birth of the cohort. Although the cohort was closed to recruitment in 2000, an additional 12 men and one woman from the last report have reached their five-year qualifying period since the cut-off dates of this analysis because of updates to their employment history reflecting subsequent work now meeting eligibility criteria. There have not been any withdrawals since the last report.

The number of new entrants is now very small in relation to the whole cohort. This means that the cohort is aging as a whole. This factor strongly influences the death rate from most non-infectious diseases, as well as increasing the incidence (rate of occurrence in the population) of many cancers, e.g., prostate cancer. When estimating the risk of death or disease from a specific cause within the *Health Watch* population compared to the general population, adjustments are made to account for the advancing age of the *Health Watch* cohort.

Table 1: Distribution of year of birth for *Health Watch* cohort members

Year of Birth	Men		Women		Total	
	N	%	N	%	N	%
1900-1919	78	0.5	1	0.1	79	0.4
1920-1929	1,674	10.0	52	3.8	1,726	9.6
1930-1939	2,876	17.3	143	10.4	3,019	16.7
1940-1949	4,837	29.0	270	19.7	5,107	28.3
1950-1959	4,843	29.1	401	29.2	5,244	29.1
1960-1969	2,109	12.7	396	28.8	2,505	13.9
1970-1979	249	1.5	111	8.1	360	2.0
Total	16,666	100.0	1,374	100.0	18,044	100.0

3.1.2. Person-years of Observation in the Cohort

With each succeeding calendar year, the number of years of observation increases for each surviving member of the cohort population (see 2.5.1). Each participant completes a person-

year of observation for each year since entry into the cohort until death (or emigration). *Health Watch* has now accumulated 506,877 person-years of observation in men and 38,746 person-years in women. The accumulation of person-years by calendar period is shown in Table 2.

Table 2: Person-years of observation

Sex	Number of Cohort members	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020	Total
Men	16,666	29,379	56,683	69,010	75,017	75,262	72,080	67,743	61,703	506,877
Women	1,374	1,334	3,031	4,408	5,593	6,284	6,233	6,058	5,8050	38,746

3.2. Person-years and Mortality and Cancer Incidence Rates

For this report, a little over 6% of the cohort remain classified as employed in an AIP participating company (including contract drivers).

The follow-up time of members of the cohort lost to contact was included until the cut-off date of 30/11/2020 for mortality and 31/12/2016 for cancer incidence. Estimates of SMR and SIR could therefore be underestimated because some of those lost to contact could be dead, but the error is most likely to be negligible. Deaths have occurred in the cohort since the cut-off date of 2020; however, since comparison data were not available for this period, they have not been included in these analyses.

Neither of the sensitivity analyses carried out had much impact on the results. These were removing person-years for those members who reached 90 years of age and removing these members from the analyses. For this reason, these older individuals have been included in analyses reported here so that the analyses are consistent with previous reports.

3.3. All-cause Mortality – Men and Women

As of November 30, 2020, there were a total of 4,522 deaths among men and 142 deaths among women in the cohort. The estimation of the SMR considering the follow-up time of cohort members up to the specified cut-off date is presented in Table 3. The SMR for both men and women consistently demonstrate that the mortality rate within this cohort was significantly lower compared to the general population. These results take into consideration age differences and utilise yearly rates that account for the overall increase in life expectancy observed in the Australian population over the past few decades. This low mortality rate is often noted in working groups and is described as the *healthy worker effect*.(47, 48, 49)

Table 3: All-cause mortality by sex, adjusted for age and calendar period of follow-up, compared to the Australian population

Sex	Person-Years	Observed	Expected	SMR	95% C.I.
Men	506,877	4,522	5707.12	**0.79**	**0.77 - 0.82**
Women	38,746	142	201.67	**0.70**	**0.59 - 0.83**

3.4. Cancer Incidence and Mortality – Men and Women

The incidence of cancer and the mortality rates from cancer are dealt with together in this section. Cancers are classified under the ICD-10 by morphological type (i.e. where it arises in the body) and/or by histology (cell type).

Table 4 and Table 5 show the cancer incidence and the cancer mortality in the *Health Watch* population of men and women. The SIR for cancer in men and women was the same as the general population. The mortality rate for cancer in men, however, was lower in comparison with the general male population (SMR 0.90, 95% C.I. 0.86-0.94). The low SMR for cancer is likely to be a reflection of the *healthy worker effect*. The SMR for women is also lower.

As discussed in previous *Health Watch* reports, (7, 9) a *healthy worker effect* is clearly demonstrable when mortality is used as the outcome measure, but not when cancer incidence is used. The 12th Report suggested that the *healthy worker effect* could be a consequence of greater survival rather than of a reduced disease incidence.(50)

The cancer incidence and cancer mortality data presented in Table 4 and Table 5 are not exactly comparable, as the cancer analysis has been updated only to the end of 2016, whereas the mortality analysis has been updated to the end of 2020 (as is evident from the difference in person-years of observation). Nevertheless, the differences in person-time could not account for the finding that cancer mortality is significantly reduced for men, whereas cancer incidence is not.

Table 4: All-site cancer incidence for men and women, adjusted for age and calendar period of follow-up, compared to the Australian population

Sex	Person-Years	Observed	Expected	SIR	95% C.I.
Men	452,628	4,477	4,455.70	1.00	0.98 - 1.03
Women	33,814	196	195.21	1.00	0.87 - 1.15

Table 5: All-site cancer mortality, men and women, adjusted for age and calendar period of follow-up, compared to the Australian population

Sex	Person-Years	Observed	Expected	SMR	95% C.I.
Men	506,877	1,841	2,039.49	**0.90**	**0.86 - 0.94**
Women	38,746	66	75.91	0.87	0.67 - 1.11

The Healthy Worker Effect

One cause of the "healthy worker effect" is the relative social and economic advantage of employed people, especially for people with relatively secure employment. Unemployed people as a whole tend to have lower socioeconomic status. This commonly correlates with lower income, fewer years of education, lower health status and higher age-adjusted mortality rates than employed people. Therefore, when comparing the mortality of occupational cohorts with that of the general population, the mortality rate tends to be higher in the latter due to the inclusion of a larger proportion of socially disadvantaged individuals

Another factor is that people with life-threatening conditions, such as cancer, tend not to seek or obtain employment after diagnosis: this further lowers the mortality rate in the workforce compared with the general population, especially in the years immediately following recruitment of members to the cohort into Health Watch.

3.5. Results in Women

Because of the small number of women in the study population, the ability of *Health Watch* to conduct detailed risk analyses for women is limited. Analyses focussed on major groupings of common conditions were performed.

3.5.1. Mortality by Major Cause for Women

Table 6 shows the mortality by major cause for women. We have again included metabolic disease, diabetes, nervous system diseases, and cerebrovascular disease in this report, however the numbers in these categories are still small for women. Ischaemic heart disease (IHD) and chronic obstructive pulmonary disease (COPD) are subcategories of circulatory and respiratory diseases respectively.

Because of the small number of women in the petroleum industry, and the low counts in all categories except cancer and circulatory mortality, the SMRs for the remaining other categories have wide confidence intervals and so the point estimates may be regarded as unreliable. Mortality from cancer is similar to that of the general female population. A very low mortality rate for *all causes of death* was also reported in previous reports and this SMR continues to be low. The SMR from external causes is particularly low.

Table 6: Mortality by major cause for women, adjusted for age and calendar period of follow-up, compared to the Australian population

Cause	ICD-10	Observed	Expected	SMR	95% C.I.
Cancer(Malignant)	C00 - C97, D45 - D46, D47.1, D47.3, D47.4, D47.5	66	75.91	0.87	0.67 - 1.11
Metabolic	E00 - E99	6	7.98	0.75	0.28 - 1.64
Diabetes	E10 - E14	<6	-	-	0.20 - 1.84
Nervous System Diseases	G00 - G99	12	9.56	1.25	0.65 - 2.19
Circulatory	I00 - I99	29	51.24	**0.57**	**0.38 - 0.81**
Ischaemic heart disease	I20 - I25	12	21.39	**0.56**	**0.29 - 0.98**
Cerebrovascular disease	I60 - I69	6	13.84	**0.43**	**0.16 - 0.94**
Respiratory	J00 - J99	15	16.51	0.91	0.51 - 1.50
COPD[a]	J40 - J44	9	8.52	1.06	0.48 - 2.00
Digestive	K00 - K93	<6	-	-	0.15 - 1.37
External Causes (e.g. accidents, violence, suicide)	V01 - Y98	<6	-	-	**0.02 - 0.68**
All other causes		8	22.37	**0.36**	**0.15 - 0.70**
All causes of death		142	201.67	**0.70**	**0.59 - 0.83**

[a]Chronic obstructive pulmonary disease

3.5.2. Cancer in Women

The overall and site-specific cancer incidence rates in women are shown in Table 7. The numbers for several specific cancer sites were small (<6). Breast cancer, melanoma and lung cancer have somewhat larger numbers of cases. Overall, the SIR was similar to the population rate (SIR 1.00, 95% C.I. 0.87 - 1.15), based on 196 cases.

There was a significant reduction in incidence for the *Other Cancers* category. As a result of the small number of female cancers, further analyses cannot be undertaken by workplace types, or time variables.

Table 7: Cancer incidence by major anatomical site for women, adjusted for age and calendar period of follow-up compared to the Australian population

Malignant neoplasm of:	ICD-10	Observed	Expected	SIR	95% C.I.
Colon	C18	14	15.41	0.91	0.50 - 1.52
Rectum	C19 - C21	7	6.80	1.03	0.41 - 2.12
Melanoma	C43	26	20.06	1.30	0.85 - 1.90
Breast	C50	69	63.42	1.09	0.85 - 1.38
Cervix	C53	<6	-	-	0.37 - 2.66
Kidney	C64 - C66, C68	<6	-	-	0.30 - 2.85
Bladder	C67	<6	-	-	0.34 - 4.87
Pancreas	C25	6	3.78	1.59	0.58 - 3.45
Lung	C33 - C34	20	14.32	1.40	0.85 - 2.16
Thyroid	C73	7	5.64	1.24	0.50 - 2.56
Leukaemia	C91 - C95	<6	-	-	0.38 - 2.74
Other		30	50.35	**0.60**	**0.40 - 0.85**
All Malignant		196	195.21	1.00	0.87 - 1.15

Results for Women in Health Watch

The numbers of women in the Health Watch program are very small, preventing a more detailed analysis.

Women in the industry have death rates which are lower than that of women in Australia generally.

No cancer type has occurred in a statistically significant excess, but the numbers of individual cancers remain too low for further analyses.

3.6. Mortality in Men

3.6.1. Mortality among Men by Major Cause

The SMRs for all major categories of cause of death are shown in Table 8. In all major categories, except for nervous system diseases, including that for external causes (including accidents and suicides), there were fewer deaths than expected, and so all the SMRs were below 1.0. The rates of mortality from nervous system diseases including Alzheimer and Parkinson's disease were lower than those of the Australian population, but not significantly (SMR 0.89, 95% C.I. 0.77-1.03).

Table 8: Mortality by major cause for men, adjusted for age and calendar period of follow-up, compared to the Australian population

Cause of Death	ICD-10	Observed	Expected	SMR	95% C.I.
Cancer (Malignant)	C00.- C97, D45 - D46, D47.1, D47.3, D47.4, D47.5	1,841	2039.49	**0.90**	**0.86 - 0.94**
Melanoma	C43	74	76.08	0.97	0.76 - 1.22
Prostate Cancer	C61	206	217.90	0.95	0.82 - 1.08
Metabolic Diseases	E00-E99	137	215.99	**0.63**	**0.53 - 0.75**
Diabetes	E10 - E14	97	160.96	**0.60**	**0.49 - 0.74**
Mental Diseases	F00 - F99	129	166.97	**0.77**	**0.65 - 0.92**
Nervous system diseases	G00 - G99	184	206.54	0.89	0.77 - 1.03
Alzheimer disease	G30	62	55.98	1.11	0.85 - 1.42
Parkinson disease	G20 - G22	46	52.94	0.87	0.64 - 1.16
Circulatory Disease	I00 - I994	1,282	1745.38	**0.73**	**0.69 - 0.78**
Hypertensive disease	I10 - I15	27	44.90	**0.60**	**0.40 - 0.87**
Ischaemic heart disease	I20 - I25	780	1028.88	**0.76**	**0.71 - 0.81**
Cerebrovascular disease	I60 - I69	218	310.21	**0.70**	**0.61 - 0.80**
Respiratory Diseases	J00 - J99	344	469.87	**0.73**	**0.66 - 0.81**
COPD	J40 - J44	170	262.14	**0.65**	**0.55 - 0.75**
Asthma	J45, J46	9	14.70	0.61	0.28 - 1.16
Other lung disease	J60 - J67	14	8.58	1.63	0.89 - 2.74
Asbestosis	J61	12	7.13	1.68	0.87 - 2.94
Digestive Diseases	K00 - K93	151	213.21	**0.71**	**0.60 - 0.83**
Liver disease	K70 - K77	69	106.29	**0.65**	**0.51 - 0.82**
Urinary Tract Diseases	N00 - N99	58	94.07	**0.62**	**0.47 - 0.80**
Kidney disease	N17 - N19	32	62.24	**0.51**	**0.35 - 0.73**
External Causes (e.g. accidents, violence, suicide)	V01 - Y98	254	355.69	**0.71**	**0.63 - 0.81**
Accidents	V01 - X59, Y85 - Y86	156	213.12	**0.73**	**0.62 - 0.86**
Suicide	X60 - X84, Y87	85	115.79	**0.73**	**0.59 - 0.91**
All other Causes		142	199.91	**0.71**	**0.60 - 0.84**
All Causes		4522	5,707.12	**0.79**	**0.77 - 0.82**

The mortality from asbestosis, a subcategory of lung disease, remains elevated (based on 12 deaths) compared to the general population (SMR 1.68, 95% C.I. 0.87-2.94). Rates of ischaemic heart disease (IHD) mortality, based on 780 male deaths, continue to be reduced with an SMR of 0.76, with the upper limit of the confidence interval at 0.81. The low IHD mortality rate observed in this cohort indicates that the incidence of IHD is also likely to be low within this group and comparable with that of more advantaged groups in Australian society.

3.6.2. All-cause Mortality and Time Relationships

Both internal and external comparisons have been conducted for all causes of death collectively, aiming to identify any potential associations with the era of first employment in the industry, duration of employment in the industry, and the time interval between initial employment in the industry and death. All internal analyses have been adjusted for age and calendar period of follow-up and smoking status.

All-cause mortality among men by period of first employment

Table 9 presents a comparison between male cohort members based on the period of their initial employment in the industry and the general population. For each period of employment, the SMR is significantly lower compared to the mortality rate of the Australian male population. SMRs of different subcategories cannot reliably be compared with each other, but this analysis suggests that the generally increasing SMR with earlier date of first employment is due to a low death rate (in absolute terms) in those members of the cohort who entered the industry most recently. This is probably a manifestation of the *healthy worker effect* discussed in Section 3.3 (page 37), which is commonly found to decrease (i.e. the SMR increases), as cohorts are followed over time.

Table 9: All-Cause mortality among men by period of first employment, adjusted for age and calendar period of follow-up, compared to the Australian population

Period of First Employment	Person-Years	Observed	Expected	SMR	95% C.I.
Post 1985	94,998	208	378.49	**0.55**	**0.48 - 0.63**
1975-84	196,268	898	1260.86	**0.71**	**0.67 - 0.76**
1965-74	141,601	1,517	1793.38	**0.85**	**0.80 - 0.89**
1955-64	51,520	1,194	1413.59	**0.84**	**0.80 - 0.89**
Pre 1954	22,489	705	860.80	**0.82**	**0.76 - 0.88**

Table 10 displays the internal comparison of cohort mortality rates for men, categorised based on the period of their initial employment in the industry. This comparison enables an assessment of the variations in mortality rates within the cohort based on different time periods of entry into the industry. The comparisons were made with the category of most recent entrants to the industry – members of the cohort who have started since 1985.

The RMR for all-causes combined was significantly higher for those entering the industry before 1985. There was evidence of a trend of increasing all-cause mortality with earlier date of first employment in the industry. This could be a result of a very low absolute mortality rate in the baseline group, and diminishing *healthy worker effect* over time, as shown by the data in Table 9.

Table 10: All-cause mortality among men by period of first employment, adjusted for age, calendar period of follow-up and smoking (ever vs never), compared to those employed from 1985

Period of First Employment	Person-Years	Deaths	RMR	95 % C.I.
Post 1985	94,998	208		
1975-84	196,268	898	**1.21**	**1.03 - 1.41**
1965-74	141,601	1,517	**1.43**	**1.22 - 1.68**
1955-64	51,520	1,194	**1.51**	**1.27 - 1.79**
Pre 1954	22,489	705	**1.51**	**1.26 - 1.82**

Test for heterogeneity P<0.0001 Test for trend P<0.0001

All-cause mortality among men by duration of employment

Table 11 shows the mortality rates of male cohort members according to the duration of employment in the industry compared to the general population. The findings were similar to those relating to period of entering the.

Table 11: Standardised all-cause mortality among men by duration of employment, adjusted for age and calendar period of follow-up, compared to the Australian population

Duration of Employment	Person-Years	Observed	Expected	SMR	95% C.I.
5-9 Years	93,026	303	413.86	**0.73**	**0.65 - 0.82**
10-15 Years	101,131	590	674.43	**0.87**	**0.81 - 0.95**
15-19 Years	91,054	717	864.23	**0.83**	**0.77 - 0.89**
20-24 Years	78,884	759	960.62	**0.79**	**0.73 - 0.85**
≥25 Years	142,569	2153	2791.69	**0.77**	**0.74 - 0.80**

Table 12 shows the RMR of men within the cohort according to the duration of employment in the industry. The comparisons were made with the category of shortest duration in the industry - members of the cohort who were employed between five and nine years. It should be noted that individual members of the cohort can contribute to person-years in more than one category as their duration of employment increases and they move up through duration categories over time.

Compared with the baseline group (employed for 5-9 years), the mortality rate from all causes combined decreases as duration of employment increases. As seen in the previous report, the statistically significant trend of decreasing risk with increasing duration of employment remains (P=0.0008).

Table 12: Relative all-cause mortality among men by duration of employment, adjusted for age, calendar period of follow-up and smoking (ever vs never), compared to those employed for 5-9 years

Duration of Employment	Person-Years	Deaths	RMR	95 % C.I.
5-9 Years	93,026	303		
10-15 Years	101,131	590	1.13	0.98 - 1.30
15-19 Years	91,053	717	1.02	0.89 - 1.17
20-24 Years	78,883	759	0.96	0.84 - 1.11
≥25 Years	142,569	2,153	0.93	0.82 - 1.06

Test for heterogeneity P=0.0023 Test for trend P=0.0008

All-cause mortality among men by time since first employment

Table 13 shows mortality rates for male cohort members according to the time since they first commenced employment in the industry compared to the general population. This differs from the Period of First Employment analyses where each cohort member is assigned to one category. In these analyses members move up a year for every year since first employment and can contribute person-years to multiple categories. It shows that all groups have a reduced mortality risk including a very low SMR (0.49) in the 5-9 years category.

Table 13: Standardised all-cause mortality among men by time since first employment, adjusted for age and calendar period of follow-up, compared to the Australian population

Time since first employment	Person-Years	Observed	Expected	SMR	95% C.I.
5-9 Years	40,731	40	80.93	**0.49**	**0.35 - 0.67**
10-15 Years	57,380	100	150.03	**0.67**	**0.54 - 0.81**
15-19 Years	65,817	139	237.29	**0.59**	**0.49 - 0.69**
20-24 Years	70,623	232	359.00	**0.65**	**0.57 - 0.73**
≥25 Years	272,321	4,011	4,879.85	**0.82**	**0.80 - 0.85**

Table 14 shows the mortality rates for men, compared within the cohort, according to the time since first employment in the industry. The comparisons were made with reference to those members of the cohort who were employed for the shortest duration (between five and nine years). Again, it should be noted that individual members of the cohort can contribute to person-years in more than one category as their time since first employment increases. The mortality significantly increased with time since first employment (trend test p=0.0154) and was highest in the group employed for 25 years or more. The *healthy worker effect* is known to diminish with age and is the most likely explanation for this finding.

Table 14: Relative all-cause mortality among men by time since first employment, adjusted for age, calendar period of follow-up and smoking (ever vs never), compared to the those first employed 5-9 years ago

Time since first employment	Person-Years	Deaths	RMR	95 % C.I.
5-9 Years	40,731	40		
10-15 Years	57,380	100	1.37	0.93 - 2.00
16-19 Years	65,817	139	1.19	0.81 - 1.76
20-24 Years	70,623	232	1.29	0.88 - 1.90
≥25 Years	272,321	4,011	**1.49**	**1.02 - 2.18**

Test for heterogeneity P=0. 0421 Test for trend P=0. 0154

Overall Mortality of Men in the Health Watch Cohort

For men, overall death rates were low. Death rates in all major disease categories, except nervous system diseases, were also significantly lower than the corresponding population. There was an elevated risk of death from asbestosis, however this was no longer statistically significant.

There was a significant trend of decreasing all-cause mortality with increasing duration of employment.

There was evidence of a trend by time period of first employment and time since first employment. The overall mortality was particularly low for the most recently employed men compared to the general population. It may be the low mortality in the baseline comparative group that explains the apparent increase in mortality in those first employed in earlier years, with the healthy worker effect diminishing as members age.

3.7. Cancer Incidence among Men

Site-specific cancer incidence ratios for men are shown in Table 15. This table lists the number of cases of specific cancers observed in male *Health Watch* members, the number expected based on population rates, and the calculated SIRs and 95% CIs.

Table 15: Cancer incidence by major anatomical site in men, adjusted for age and calendar period of follow-up, compared to the Australian population

Malignant neoplasm of:	ICD-10	Observed	Expected	SIR	95% C.I.
Lip, Oral Cavity and Pharynx	C00 - C14	146	183.35	**0.80**	**0.67 - 0.94**
Oesophagus	C15	74	66.31	1.12	0.88 - 1.40
Stomach	C16	112	104.10	1.08	0.89 - 1.29
Colon	C18	324	352.68	0.92	0.82 - 1.02
Rectum	C19 - C21	227	225.91	1.00	0.88 - 1.14
Liver	C22	42	67.78	**0.62**	**0.45 - 0.84**
Gallbladder	C23-C24	24	23.89	1.00	0.64 - 1.50
Pancreas	C25	73	94.35	**0.77**	**0.61 - 0.97**
Larynx	C32	40	49.28	0.81	0.58 - 1.11
Lung	C33 - C34	413	490.34	**0.84**	**0.76 - 0.93**
Melanoma	C90	552	456.31	**1.21**	**1.11 - 1.31**
Mesothelioma	C45	63	39.55	**1.59**	**1.22 - 2.04**
Connective Tissue	C47 - C49	22	25.15	0.87	0.55 - 1.32
Prostate	C61	1371	1,223.58	**1.12**	**1.06 - 1.18**
Testis	C62	30	23.61	1.27	0.86 - 1.81
Bladder	C67	133	131.39	1.01	0.85 - 1.20
Kidney	C64	131	123.84	1.06	0.88 - 1.26
Eye	C69	14	11.53	1.21	0.66 - 2.04
Brain & Nervous System	C71	68	61.96	1.10	0.85 - 1.39
Thyroid	C73 - C75	24	28.43	0.84	0.54 - 1.26
Non-Hodgkin lymphoma	C82 - C86, C96	164	162.54	1.01	0.86 - 1.18
Multiple myeloma	C90	66	59.96	1.10	0.85 - 1.40
Leukaemia	C91 - C95	98	127.67	**0.77**	**0.62 - 0.94**
Acute lymphatic leukaemia	C910	<6	-	-	0.14 - 2.05
Chronic lymphatic leukaemia	C911	45	59.94	0.75	0.55 - 1.00
Acute myeloid leukaemia	C920, C923 - C926, C928, C930, C940, C942, C944 - C945	24	32.15	0.75	0.48 - 1.11
Chronic myeloid leukaemia	C921	13	11.67	1.11	0.59 - 1.91
Other leukaemia	C91 - 95	13	19.64	0.66	0.35 - 1.13
Unspecified cancer site		94	108.18	0.87	0.70 - 1.06
Myelodysplastic Syndrome	D46	41	33.75	1.21	0.87 - 1.65
Other sites		122	147.03	**0.83**	**0.69 - 0.99**
All Malignant		4477	4,455.70	1.00	0.98 - 1.03

[a]Myelodysplastic Syndrome (MDS) cases diagnosed after 2003 are included in this analysis only. The National population data set for MDS required to calculate the SMR, is only available from 2003 onwards.

There remains a statistically significant excess rate of mesothelioma and melanoma of the skin which was also observed in previous reports.(9, 23, 28) The excess risk of prostate cancer was also observed previously.(28)

The risk of leukaemia continues to decrease in the cohort and is now a significantly lower risk in the cohort compared with the Australian population (SIR 0.77, 95% C.I. 0.62-0.94). The risk of myelodysplastic syndrome (MDS) was increased, however the increase was not statistically significant and remains similar to previous reports.(23, 28) MDS has been found to be associated with benzene exposure in the petroleum industry.(22)

There was a statistically significant reduction in the risk of lung and liver cancer and cancer of the lip, oral cavity, and pharynx. These reductions were also observed in previous reports. (9, 23, 28)

3.7.1. Cancer and Time Relationships for Men

Cancer incidence and mortality according to period of first employment

Table 16 shows that there was a significant trend in cancer incidence with period of first employment (p=0.0223). The trend of cancer mortality rates with period of first employment was more apparent, (p=0.0009), and this trend continues to strengthen compared to the previous report.(28) This could be a result of the very low overall mortality in the baseline group. Although the overall cancer mortality rates are increased in those employed before 1985 compared to the baseline group employed post 1985, there is a significant decrease in cancer mortality when the cohort is compared to the Australian population of comparable age.

Table 16: Cancer incidence and cancer mortality by period of first employment, adjusted for age and calendar period of follow-up, and ever/never smoker compared to those employed after 1985

Period of first Employment	Cancers	Relative Incidence RIR	95 % C.I.	Deaths	Relative Mortality RMR	95 % C.I.
Post 1985	367			87		
1975 - 84	1,254	1.06	0.94 - 1.20	441	**1.47**	**1.16 - 1.86**
1965 - 74	1,509	1.10	0.96 - 1.25	626	**1.61**	**1.26 - 2.05**
1955 - 64	882	1.16	0.99 - 1.34	444	**1.77**	**1.35 - 2.31**
Pre 1954	465	**1.21**	**1.02 - 1.44**	243	**1.77**	**1.32 - 2.37**

Incidence: Test for heterogeneity P=0.2447 Test for trend P=0.0223
Mortality: Test for heterogeneity P=0.0007 Test for trend P=0.0009

Cancer incidence and mortality according to duration of employment

Table 17 shows the relative cancer incidence and relative cancer mortality by duration of employment. There was no significant trend in cancer incidence nor cancer mortality with increasing duration of employment. An additional analysis was conducted to examine whether the outcomes of cancer mortality would be affected by comparing to a larger reference group. The results of this analysis, using the reference group of 5-12 years, instead of 5-9 years are presented in Table 18. In this analysis, there was a lower cancer mortality rate in the second employment duration category (13-15 years), and a noticeable decreasing

trend between cancer mortality and duration of employment became evident (P=0.04). This suggests that the increased risk seen in the 10-15 year duration of employment (

Table 17) was likely an artefact of the small comparison group.

Table 17: Cancer incidence and cancer mortality by duration of employment, adjusted for age, calendar period of follow-up, and smoking (ever vs never), compared to those employed for 5-9 years

Duration of Employment	Cancers	Relative Incidence RIR	95 % C.I.	Deaths	Relative Mortality RMR	95 % C.I.
5-9 Years	397			122		
10-15 Years	608	**0.97**	**0.85 - 1.10**	266	**1.29**	**1.04 - 1.60**
15-19 Years	678	**0.87**	**0.77 - 0.99**	286	1.05	0.84 - 1.30
20-24 Years	754	**0.90**	**0.80 - 1.03**	310	1.03	0.83 - 1.27
≥25 Years	2,037	1.00	0.89 - 1.12	857	1.03	0.84 - 1.25

Incidence: Test for heterogeneity P=0.0271 Test for trend P=0.1003
Mortality: Test for heterogeneity P=0.0139 Test for trend P=0.4172

Table 18: Cancer mortality by duration of employment, adjusted for age and calendar period of follow-up, and smoking (ever vs never), compared to those employed for 5-12 years

Duration of Employment	Cancer Deaths	Relative Mortality RMR	95 % C.I.
5-12 Years	280		
13-15 Years	108	1.07	0.86 - 1.34
15-19 Years	286	**0.90**	**0.76 - 1.06**
20-24 Years	310	**0.88**	**0.75 - 1.04**
>=25 Years	857	**0.88**	**0.76 - 1.02**

Mortality: Test for heterogeneity P=0.2110 Test for trend P=0.0417

Cancer incidence and cancer mortality by time since first employment

Table 19 presents the relative cancer incidence and cancer mortality rates based on the time elapsed from the date of first employment to the diagnosis of cancer or occurrence of cancer-related death. Note that this is not employment duration but rather time elapsed since first employed. The findings were very similar to those found with duration of employment. There was no relationship between cancer incidence and time since first employment.

Cancer mortality for all subgroups except those employed for 15-19 years prior to diagnosis were increased relative to those whose cancer arose within nine years of joining the industry. This is likely to be attributable to a low absolute mortality rate in the baseline category of those members of the cohort employed 5-9 years previously.

Table 19: Cancer incidence and cancer mortality by time since first employment, adjusted for age and calendar period of follow-up, and smoking (ever vs never), compared to those first employed 5-9 years ago

Time since first Employment	Cancers	Relative Incidence RIR	95 % C.I.	Deaths	Relative Mortality RMR	95 % C.I.
5-9 Years	53			7		
10-15 Years	136	1.20	0.87 - 1.67	44	**3.18**	**1.40 - 7.22**
15-19 Years	207	0.99	0.71 - 1.38	55	2.23	0.97 - 5.15
20-24 Years	384	1.07	0.77 - 1.48	101	**2.38**	**1.04 - 5.46**
≥25 Years	3696	1.17	0.85 - 1.62	1634	**2.73**	**1.20 - 6.21**

Incidence: Test for heterogeneity P=0.11131 Test for trend P=0.1348
Mortality: Test for heterogeneity P=0.0151 Test for trend P=0.1672

Cancer Incidence and Mortality among Men in the Health Watch Cohort

The chance of getting cancer is the same for men in the petroleum industry as for the general Australian population. This is so for all cancers combined and for most individual cancer types. However, some cancers – mesothelioma, prostate cancer and melanoma of the skin, continue to occur at significantly higher rates compared with the general population. The increased incidence of prostate cancer, and the absence of an increased prostate cancer mortality, suggest a higher rate of screening compared to the general population.

There was a significant reduction in rates of liver and lung cancer and cancers of the lip, oral cavity and pharynx. Leukaemia risk continues to decrease and is now significantly reduced compared with the general population. The age-adjusted mortality rate from all cancers combined was significantly less than in the general population.

Those who worked in the industry in earlier times have not been at a significantly greater risk of developing cancer compared to those who entered the industry more recently. However, cancer mortality rates were higher for those who entered the industry before 1985 compared to those who started later, and there is a trend for higher mortality associated with earlier starting periods.

Cancer and mortality rates do not appear to be related to duration in the industry or time since first employment.

3.7.2. Workplace Type and Health Outcomes among Men

Analyses were undertaken for the five principal workplace types - refineries, terminals, airports, onshore production, and offshore production. Men were grouped by the site of their most recent job.

Table 20: Numbers of male members of the cohort in each workplace type

Workplace Type	Number of men in cohort	% of men in cohort	Person-years	% of Person-years
Refinery	6,487	38.9	200,270	39.5
Terminal	6,468	38.8	194,310	38.3
Airport	604	3.6	18,901	3.7
Onshore production	2,357	14.1	69,510	13.7
Offshore Production	728	4.4	23,232	4.6
Total	16,666	100.0	506,877	100.0

The all-cause mortality by workplace type is shown in Table 21. All-cause mortality continues to be significantly reduced in all workplace types, which is consistent with the mortality risk in the cohort overall.

Table 21: All-cause mortality in men by workplace type, adjusted for age and calendar period of follow-up, compared to the Australian population

Workplace Type	Person-Years	Observed	Expected	SMR	95% C.I.
Refinery	200,270	1731	2,343.90	**0.74**	**0.70 - 0.77**
Terminal	194,310	2092	2,406.41	**0.87**	**0.83 - 0.91**
Airport	18,901	182	252.52	**0.72**	**0.62 - 0.83**
Onshore Production	69,510	415	534.28	**0.78**	**0.70 - 0.86**
Offshore Production	23,232	102	167.55	**0.61**	**0.50 - 0.74**
Total	506,877	4522	5,707.12	**0.79**	**0.77 - 0.82**

Table 22 shows mortality from ischaemic heart disease by workplace type. SMRs were lower than expected in each workplace type and the difference was statistically significant except amongst offshore production workers where there were small numbers.

Table 22: Ischaemic heart disease (ICD-10 I20-I25) mortality for men by workplace type, adjusted for age and calendar period of follow-up, compared to the Australian population

Workplace Type	Person-Years	Observed	Expected	SMR	95% C.I.
Refinery	200,270	288	427.89	**0.67**	**0.60 - 0.76**
Terminal	194,310	383	440.38	**0.87**	**0.78 - 0.96**
Airport	18,901	24	45.47	**0.53**	**0.34 - 0.79**
Onshore Production	69,510	66	88.08	**0.75**	**0.58 - 0.95**
Offshore Production	23,232	19	26.72	0.71	0.43 - 1.11
Total	506,877	780	10,28.88	**0.76**	**0.71 - 0.81**

Table 23 shows the incidence of cancer in the different workplace types. All five categories of workplace type, except for Offshore Production, showed total cancer risks similar to that of the general population. Offshore Production had a significantly lower risk of cancer compared with the Australian population.

Table 23: Cancer incidence among men by workplace type, adjusted for age and calendar period of follow-up, compared to the Australian population

Workplace Type	Person-Years	Observed Cancers	Expected Cancers	SIR	95% C.I.
Refinery	178,905	1,757	1,778.37	0.99	0.94 - 1.04
Terminal	174,516	1,902	1,838.00	1.03	0.99 - 1.08
Airport	17,003	191	190.99	1.00	0.86 - 1.15
Onshore Production	61,135	490	482.56	1.02	0.93 - 1.11
Offshore Production	205,02	137	163.29	**0.84**	**0.70 - 0.99**
Total	452,628	4,477	44,55.70	1.00	0.98 - 1.03

As shown in Table 24, cancer mortality was lower than population rates in all workplace types, but the difference was statistically significant for refinery workers and Offshore Production workers only.

Table 24: Cancer mortality among men by workplace type, adjusted for age and calendar period of follow-up, compared to the Australian population

Workplace Type	Person-Years	Observed Cancer Deaths	Expected Cancer Deaths	SMR	95% C.I.
Refinery	200,270	696	826.43	**0.84**	**0.78 - 0.91**
Terminal	194,310	845	855.55	0.99	0.92 - 1.06
Airport	18,901	73	89.50	0.82	0.64 - 1.03
Onshore Production	695,10	180	201.13	0.89	0.77 - 1.04
Offshore Production	23,232	47	65.98	**0.71**	**0.52 - 0.95**
Total	506,877	1841	2,039.49	**0.90**	**0.86 - 0.94**

Health and Workplace Type

The health of male employees as measured from the Health Watch results differed very little between those who worked at the various types of workplaces in the industry, such as upstream production sites and downstream refineries and terminals.

That is, the chances of dying, or of getting cancer or heart disease were very similar no matter where men in Health Watch worked.

3.8. Non-malignant Disease from Asbestos Exposure

Apart from its association with certain types of cancer (mesothelioma and lung cancer), asbestos exposure can cause non-malignant conditions, including pleural plaques and asbestosis. Pleural plaques are deposits of fibrous tissue (sometimes becoming calcified) on the pleural lining of the chest cavity. They are the commonest manifestation of asbestos exposure, but in general, they are not disabling.

Asbestosis is a disease affecting the lung tissue itself, which can cause breathlessness and other respiratory symptoms, associated disability such as reduced walking tolerance, and it can be fatal. It is generally accepted that asbestos exposure increases the risk of lung cancer.(51, 52, 53)

Twelve members of the *Health Watch* cohort have died from asbestosis, with one additional death since the previous report.(28) This increase is not statistically significant (SMR 1.68, C.I. 0.87-2.94).

Although mortality from asbestosis was elevated in the cohort compared to the general population, this does not represent the full picture because over 120 members of the cohort have reported asbestos related illnesses. It is important to note that these self-reported illnesses were not validated in any health database and were therefore not included in any analyses. Asbestosis is not necessarily a fatal condition, and it is not possible to identify all living cases. Unlike cancer, there is no Australian register for asbestosis which have not resulted in death.

The 12th Report (7) examined the reporting of asbestos related diseases by members of the cohort and stated that: "It is likely that these figures understate the prevalence of effects of asbestos exposure, especially of pleural plaques. Not all members of the cohort reply to the periodic questionnaires. Moreover, since pleural plaques commonly produce no symptoms, they may remain undiagnosed unless the participant has a chest x-ray. Full enumeration of these effects of asbestos exposure would require a study of different design to *Health Watch*."

Non-malignant Asbestos Diseases

Non-malignant asbestos-related diseases were found in the cohort, both from the mortality data and from self-reports. The significance of the self-reported findings cannot be assessed because there are no suitable comparative data collected in the general population. However, the voluntary nature of the reporting probably underestimates the prevalence in the cohort.

4. HEALTH OUTCOMES IN SPECIFIC JOBS

The ability to assess risk in particular jobs as defined by their API Job code is recognised to be a useful method of assessing risk in the industry e.g., refinery workers may have very different jobs having different exposures. However, analysing by API Job code is limited by the numbers of employees in any job.
The job groups analysed in this report are:

- *Drivers* (NB295x)
- *Refinery operators* (not including ship personnel) (BA, BB, BC, HX, IB, PA, PB, PC, RF)
- *Terminal operators* (BA, BB, BC, HX, IB, NA, PA, PC, RF) and *Maintenance* (refinery or terminal based not upstream) (IB, CA, CB, CC, CD, CE, CF, DA, DB, DC, DD, EA, EB, EC, FA, FB, GX, MX)
- *Office workers* (AX)

Each person's full job history since 1980 was checked and categorised according to whether the person has ever held the job classification. Those who have held more than one job will appear in each category in the analysis, so their deaths and person-years are counted more than once.

Analysis has been done for some major health outcomes including all-cause mortality, ischaemic heart disease, cancer mortality, and deaths by external cause in addition to cancer incidence. For many other health outcomes, numbers were too low to be reliable when sub-divided by specific jobs.

4.1. All-cause Mortality in Men by Job Group

As shown in Table 25, all-cause mortality by job group was similar to the all-cause-mortality for the male members of the whole cohort (SMR 0.71, C.I. 0.68-0.75). Those members who ever worked in offices showed the lowest mortality rate.

Table 25: All-cause mortality among men by Job Group (ever held), adjusted for age and calendar period of follow-up, compared to the Australian population

Job	Person-Years	Observed	Expected	SMR	95% C.I.
Driver	70,830	715	816.97	**0.88**	**0.81 - 0.94**
Refinery	101,036	826	1,102.21	**0.75**	**0.70 - 0.80**
Terminal	66,462	736	749.94	0.98	0.91 - 1.05
Maintenance	119,621	1,171	1,339.02	**0.87**	**0.83 - 0.93**
Office	177,429	1,480	2,074.78	**0.71**	**0.68 - 0.75**

4.2. Cancer Incidence in Men by Job Group

There remained an increase in all-cancer incidence in drivers (Table 26) which was significantly higher than that of the general population (SIR 1.11, 95% C.I. 1.03-1.19). This was also found in the previous two reports. (23, 28)

Table 26: Cancer incidence among men by Job Group (ever held), adjusted for age and calendar period of follow-up, compared to the Australian population

Job	Person-Years	Observed	Expected	SIR	95% C.I.
Driver	63,856	745	671.03	**1.11**	**1.03 - 1.19**
Refinery	90,451	922	888.51	1.04	0.97 - 1.11
Terminal	59,827	599	589.15	1.02	0.94 - 1.10
Maintenance	107,325	998	1,024.58	0.97	0.91 - 1.04
Office	158,535	1,577	16,01.71	0.98	0.94 - 1.03

4.1. Cancer Mortality in Men by Job Group

As shown in Table 27, there were no excesses in all-cancer mortality in any of the occupational groups studied including drivers. The cancer mortality rates were only significantly lower than the population rates in office workers and were similar to the expected rate for all other job groups.

Table 27: Cancer mortality in men by Job Group (ever held), adjusted for age and calendar period of follow-up, compared to the Australian population

Job	Person-Years	Observed	Expected	SMR	95% C.I.
Driver	70,830	284	301.00	0.94	0.84 - 1.06
Refinery	101,036	363	401.87	0.90	0.81 - 1.00
Terminal	66,462	290	268.30	1.08	0.96 - 1.21
Maintenance	119,621	451	471.87	0.96	0.87 - 1.05
Office	177,429	619	739.85	**0.84**	**0.77 - 0.91**

4.1. Ischaemic Heart Disease (ICD-10 I20-125) Mortality in Men by Job Group

Ischaemic heart disease mortality was lower in the cohort as a whole, compared to the general population (SMR 0.76, 95% C.I. 0.71-0.81). Table 28 shows a reduction in IHD in drivers, refinery workers, and office workers.

Table 28: Ischaemic heart disease (ICD-10 I20-125) mortality in men by Job Group (ever held), adjusted for age and calendar period of follow-up, compared to the Australian population

Job	Person-Years	Observed	Expected	SMR	95% C.I.
Driver	70,830	121	145.72	**0.83**	**0.69 - 0.99**
Refinery	101,036	123	195.19	**0.63**	**0.52 - 0.75**
Terminal	66,462	154	136.40	1.13	0.96 - 1.32
Maintenance	119,621	227	244.31	0.93	0.81 - 1.06
Office	177,429	240	373.83	**0.64**	**0.56 - 0.73**

4.2. Mortality from External Causes: (eg Accidents,Violence and suicide (ICD-10 V00-V99, W00-W99, X00-X99, Y00-Y99) in Men by Job Group

Table 29 demonstrates that the point estimates of mortality resulting from accidents or violence in each of the occupational groups examined were lower than those of the general population. Among the occupational groups, the drivers exhibited the highest mortality rate, but this was similar to the expected rate (SMR 0.93, C.I. 0.68-1.25).

Table 29: Mortality from External Causes (ICD-10 V00-V99, W00-W99, X00-X99, Y00-Y99) in men by Job Group (ever held), adjusted for age and calendar period of follow-up, compared to the Australian population

Job	Person-Years	Observed	Expected	SMR	95% C.I.
Driver	70,830	45	48.35	0.93	0.68 - 1.25
Refinery	66,462	37	46.64	0.79	0.56 - 1.09
Terminal	101,036	52	69.21	**0.75**	**0.56 - 0.99**
Maintenance	119,621	61	85.34	**0.71**	**0.55 - 0.92**
Office	177,429	68	125.93	**0.54**	**0.42 - 0.68**

4.3. Incidence of Cancer and Mortality among Drivers

Table 30 presents the cancer incidence rates for selected major anatomical sites in drivers. There was an elevation in the total cancer incidence rate among drivers (SIR 1.11, 95% C.I. 1.03-1.19). Although most of the broad cancer categories were somewhat raised among drivers, the only statistically significantly raised risks were for melanoma (SIR 1.28, 95% C.I 1.02-1.58) and prostate cancer (SIR 1.18, 95% C.I. 1.03-1.35). The incidence of prostate cancer was elevated in the 14th Report but the increase was then not statistically significant.

There were small numbers in many of the individual cancer types which resulted in wide confidence intervals. Cancer of the oesophagus was in excess, (SIR 1.60, 95% C.I. 0.91-2.60) as was cancer of the bladder (SIR 1.29, 95% C.I. 0.83-1.90) but these excesses were not statistically significant. Because there were only 16 and 25 cases respectively, it was not possible to conduct a meaningful analysis in terms of time-related factors. The lung cancer incidence rate in drivers was similar to that of the general population.

Internal comparisons of mortality (

Table **31**) and selected cancer analyses (Table 32) were conducted between cohort members who were ever a tanker driver and those who only worked in an office and adjusted for age, calendar period and smoking.

Drivers had an increased overall mortality compared to individuals working exclusively in offices (RMR 1.13, 95% C.I. 1.02-1.25). The cancer mortality rates were similar between these two groups and aligned with the results from the previous report. Drivers continue to exhibit a higher mortality from external causes compared to office-only workers (SMR 1.06, 95% C.I. 1.20-3.21).

Although leukaemia demonstrated a statistically elevated rate among drivers compared to office-only workers, it is important to note that the number of cases was small. The incidence of bladder cancer among drivers, in comparison to individuals working exclusively in offices, continues to be elevated, but the difference is no longer statistically significant.

Table 30: Cancer incidence by selected anatomical site, for drivers by ICD-10 codes, adjusted for age and calendar period of follow-up, compared to the Australian population.

Malignant neoplasm of:	Observed	Expected	SIR	95% C.I.
Lip, Oral cavity, and Pharynx	29	27.32	1.06	0.71 - 1.52
Oesophagus	16	10.00	1.60	0.91 - 2.60
Stomach	20	15.55	1.29	0.79 - 1.99
Colon	58	53.29	1.09	0.83 - 1.41
Rectum	39	34.30	1.14	0.81 - 1.55
Liver	<6	-	-	0.16 - 1.17
Gallbladder	<6	-	-	0.07 - 2.01
Pancreas	14	14.16	0.99	0.54 - 1.66
Larynx	6	7.53	0.80	0.29 - 1.73
Lung	72	73.78	0.98	0.76 - 1.23
Melanoma	87	68.01	**1.28**	**1.02 - 1.58**
Mesothelioma	8	6.05	1.32	0.57 - 2.61
Connective Tissue	6	3.70	1.62	0.59 - 3.53
Prostate	222	188.15	**1.18**	**1.03 - 1.35**
Testis	<6	-	1.74	0.57 - 4.06
Bladder	25	19.43	1.29	0.83 - 1.90
Kidney	26	18.55	1.40	0.92 - 2.05
Eye	<6	-	-	0.14 - 4.19
Brain & Nervous System	10	9.26	1.08	0.52 - 1.99
Thyroid	6	4.06	1.48	0.54 - 3.22
Non-Hodgkin lymphoma	21	24.31	0.86	0.53 - 1.32
Multiple myeloma	12	9.02	1.33	0.69 - 2.32
Leukaemia	19	19.01	1.00	0.60 - 1.56
Acute lymphatic leukaemia	-	-	-	-
Chronic lymphatic leukaemia	10	9.08	1.10	0.53 - 2.03
Acute myeloid leukaemia	<6	-	-	0.13 - 1.84
Chronic myeloid leukaemia	<6	-	-	0.02 - 3.32
Other leukaemia	<6	-	-	0.56 - 4.03
Unspecified cancer site	12	15.90	0.75	0.39 - 1.32
Myelodysplastic Syndrome	<6	-	-	0.22 - 2.07

Other sites	17	21.62	0.79	0.46 - 1.26
All Malignant	745	671.03	**1.11**	**1.03 - 1.19**

Table 31: Relative mortality risk of Ever Drivers compared with Only Ever Office workers.

	Job Type	Current Analysis				15th Report	
		Person-Years	Deaths	RMR	95 % C.I.	RMR	95 % C.I.
All-cause Mortality	Office only	69,300	804				
	Driver ever	70,830	715	**1.13**	**1.02 - 1.25**	1.07	0.95 - 1.21
Cancer Mortality	Office only	69,300	321				
	Driver ever	70,830	284	1.00	0.85 - 1.18	1.03	0.85 - 1.24
IHD Mortality	Office only	69,300	135				
	Driver ever	70,830	121	1.20	0.93 - 1.55	1.12	0.84 - 1.48
External Mortality	Office only	69,300	26				
	Driver ever	70,830	45	**1.96**	**1.20 - 3.21**	**2.12**	**1.21 - 3.72**

Table 32: Relative cancer incidence of Ever Drivers compared with Only Ever Office workers

	Job Type	Current Analysis				15th Report	
		Person-Years	Cancer	RIR	95 % C.I.	RIR	95 % C.I.
All Cancer	Office only	62,084	746				
	Driver ever	63,856	745	1.07	0.96 - 1.18	1.11	0.99 - 1.25
Prostate Cancer	Office only	62,084	228				
	Driver ever	63,856	222	0.98	0.81 - 1.18	0.94	0.76 - 1.16
Leukaemia	Office only	62,084	9				
	Driver ever	63,856	19	**2.36**	**1.05 - 5.29**	**2.70**	**1.09 - 6.70**
Kidney Cancer	Office only	62,084	17				
	Driver ever	63,856	26	1.60	0.86 - 2.99	1.44	0.73 - 2.82
Bladder Cancer	Office only	62,084	19				
	Driver ever	63,856	25	1.49	0.81 - 2.74	**3.20**	**1.45 - 7.07**

Results for Men by Job Group in Health Watch

Overall mortality rates were significantly reduced for men in Health Watch compared with the general population rates in each of the job groups except terminal workers. Cancer mortality rates were significantly lower among office workers but not for other Job Groups.

When compared to the general population, mortality rates from heart disease were significantly lower in drivers, refinery workers and office workers. In terminal operators and maintenance workers the risk was similar to that of the general population

Death from external causes was statistically significantly lower than that of the general population for terminal, maintenance, and office workers. When compared with office-only workers, drivers exhibited a statistically significant increased risk of all-cause mortality and mortality from external causes such as accidents and suicides.

Cancer incidence for all job groups was similar to that of the population as a whole except for drivers where the overall risk of cancer was statistically significantly elevated. Leukaemia remains significantly elevated in the drivers group compared with office-only workers but numbers were small. These cancers were not elevated when compared to the general population.

5. LIFESTYLE FACTORS AMONG MALE MEMBERS OF THE COHORT

5.1. Tobacco Smoking

5.1.1. Smoking Status

The cohort members' smoking status used in these analyses were based on smoking habits reported at initial and later interviews. Additional information has been derived from postal surveys of all retired and resigned members carried out during 1994, 1996 and 1999. Data were also derived from the Health Letters, the last one being in 2018. The latest information on smoking category was used in the analyses below.

In the 11th *Health Watch* Report, (29) the smoking prevalence was compared with national smoking data based on 1995 estimates, using direct standardisation for age. The *Health Watch* male smoking rate was 24.1% compared with the Australian population rate of 28.2%. On this basis, the age-standardised smoking prevalence was slightly lower than that of the Australian national population at the time. In the 12th Report, updated figures were used based on the proportion of Australian smoking rates from 1980 to 2001.(54) Age-specific comparisons showed that for older people (over 50) the smoking rates were 5-10% higher in *Health Watch* but for the younger people (under 30) the smoking rates in *Health Watch* were much lower, about half of that in the general population.

Figure 2 shows that a minority of men in the *Health Watch* cohort smoke and comparison with previous reports show that the number of ex-smokers continue to increase.

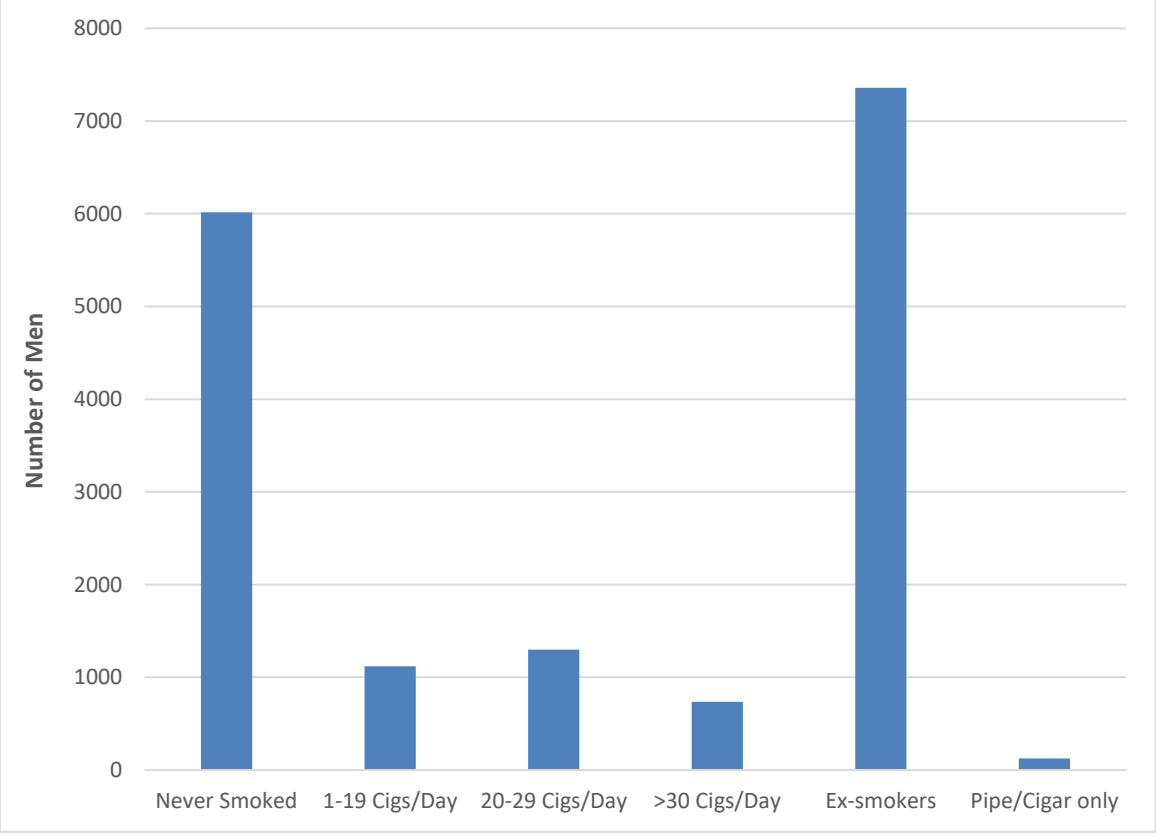

Figure 2: Latest smoking status of the men in the *Health Watch* cohort

Table 33 shows that some of the data used for the smoking analyses were collected as long ago as the early 1980s. It is possible that some of these individuals have changed their smoking habits but have not informed the study team. Since more individuals reported being smokers than being non-smokers and the trend in Australia has been to quit, it is probable that a survey of current smoking habits would report a reduction in smoking rates. That is, it is possible that fewer of the surviving older people in the cohort (those recruited in Surveys 1 and 2) remain smokers.

Table 33: Source of most recent smoking data for men in the cohort.

Source of Data	Period	Number	Percentage
Survey 1-3	1981-1993	5,423	32.5
Survey 4	1996-2000	2,455	14.7
Survey 5	2003	814	4.9
Health letter updates	Various	7,974	47.8
Total		166,66	100.0

Table 34 is a breakdown of 'ever smokers' in each main job group. The drivers' group had the highest proportion of ever smokers at 72.66% while office workers were the least likely to have ever smoked (59.48%). It should be noted that many of these 'ever smokers' could now be ex-smokers.

Table 34: Number of 'ever smokers' in each main job category

Job	Number of Men	Number of Ever Smokers	Percentage
Driver	2,165	1,572	72.6
Refinery	3,209	2,220	69.2
Terminal	2,223	1,556	70.0
Maintenance	3,905	2,588	66.3
Office	5,765	3,425	59.4

5.1.2. Smoking and All-cause Mortality among Men

In Table 35, the relative mortality ratios among men for all-cause mortality are shown according to smoking habit. These tables compare various categories of smokers relative to a baseline of those who have never smoked.

The comparison clearly shows a marked increase in age-adjusted mortality with increasing tobacco use. Men smoking up to 19 cigarettes a day have over twice the age-adjusted death rate from all causes combined, compared with those who have never smoked. For those smoking 20-29 cigarettes per day there was over a threefold increase in risk, and there was close to a four-fold risk at 30+ cigarettes per day.

As in the previous reports, ex-smokers also had an increase in mortality risk, although this increase was much less than that for current smokers (RMR 1.15, 95% C.I. 1.07-1.23). The trend for increasing age-adjusted mortality with increasing smoking level was highly statistically significant across the smoking levels. (Pipe and ex-smokers were excluded from

the trend tests in this section). This analysis once again showed a strong association between smoking and ill-health as did the results from previous *Health Watch* reports.

Table 35: All-cause male mortality by smoking category, adjusted for age and calendar period of follow-up, compared to those who never smoked

Smoking Category	Person-Years	Deaths	RMR	95 % C.I.
Never smoked	185,144	1,103		
1-19 / day	31,598	301	**2.15**	**1.89 - 2.44**
20-29 / day	33,396	521	**3.38**	**3.04 - 3.75**
30+ / day	18,685	351	**3.99**	**3.54 - 4.50**
Ex-smoker	234,949	2,210	**1.15**	**1.07 - 1.23**
Pipe/cigar only	3,104	36	**2.03**	**1.45 - 2.83**

Test for heterogeneity P<0.0001 Test for trend P<0.0001

5.1.3. Smoking and Ischaemic Heart Disease (ICD-10 I20-I25)

Many studies have shown that smoking is a major risk factor for ischaemic heart disease and this is also seen in the *Health Watch* cohort. Table 36 shows that smoking dramatically affects the chance of dying from heart attack for men in the *Health Watch* cohort. It is reasonable to assume that smoking similarly increases the risk of suffering a heart attack, even if death is not the outcome. Quitting smoking dramatically reduced the risk of ischaemic heart disease risk and was not statistically elevated for those who have stopped smoking.

Table 36: Ischaemic heart disease mortality (ICD-10 I20-I25) among men by smoking category, adjusted for age and calendar period of follow-up, compared to those who never smoked

Smoking Category	Person-Years	IHD Deaths	RMR	95 % C.I.
Never smoked	185,144	178		
1-19 / day	31,598	57	**2.52**	**1.87 - 3.40**
20-29 / day	33,396	94	**3.57**	**2.77 - 4.59**
30+ / day	18,685	73	**4.74**	**3.60 - 6.24**
Ex-smoker	234,949	367	1.13	0.95 - 1.36
Pipe/cigar only	3,104	11	**3.67**	**2.00 - 6.76**

Test for heterogeneity P<0.0001 Test for trend P<0.0001

5.1.4. Smoking and Cancer among Men

Table 37 and Table 38 show the relationship between total cancer incidence and total cancer mortality and smoking. As with all-cause mortality, both outcomes show a striking increase in risk with increasing tobacco use. As reported previously (28), ex-smokers appeared to have a somewhat greater risk of cancer and cancer mortality compared to those who have never smoked, however this risk was much lower than that found amongst those who continued to smoke.

Table 37: Cancer incidence among men by smoking category, adjusted for age and calendar period of follow-up, compared to those who never smoked

Smoking Category	Person-Years	All Cancers	RIR	95% C.I.
Never smoked	164,004	1,284		
1-19 / day	28,041	243	**1.26**	**1.10 - 1.45**
20-29 / day	30,036	356	**1.59**	**1.42 - 1.79**
30+ / day	16,930	230	**1.80**	**1.56 - 2.07**
Ex-smoker	210,863	2,342	**1.11**	**1.03 - 1.18**
Pipe/cigar only	2,754	22	0.94	0.61 - 1.43

Test for heterogeneity P<0.0001 Test for trend P<0.0001

Table 38: Cancer mortality among men by smoking category, adjusted for age and calendar period of follow-up, compared to those who never smoked

Smoking Category	Person-Years	Cancer Deaths	RMR	95 % C.I.
Never smoked	185,144	412		
1-19 / day	31,598	131	**2.35**	**1.93 - 2.87**
20-29 / day	33,396	235	**3.73**	**3.17 - 4.38**
30+ / day	18,685	154	**4.31**	**3.58 - 5.19**
Ex-smoker	234,949	898	**1.26**	**1.12 - 1.42**
Pipe/cigar only	3,104	11	1.53	0.84 - 2.79

Test for heterogeneity P<0.0001 Test for trend P<0.0001

Table 39 shows the relationship between smoking and lung cancer incidence. For this outcome, the association with smoking was stark; a 12-fold increase in risk in those smoking up to 19 cigarettes per day compared with the risk in those who have never smoked, a nearly 25-fold increase in risk for those who smoke 20-29 cigarettes per day, and a nearly 40-fold increase in risk for those who smoke 30+ cigarettes per day. Those who reported having quit smoking had over a 5-fold increase in risk compared to those who never smoked. The risks of lung cancer were slightly lower than those demonstrated in the last report, however, a strong association exists with lung cancer and the number of cigarettes smoked.

This analysis reaffirms that lung cancer in people who have never been active smokers was a rare disease. There were only 21 lifelong non-smokers in the cohort who have developed lung cancer, a small baseline group, so the estimates of increasing risk with increasing tobacco use were only approximate. Nevertheless, one of the strengths of *Health Watch* is that the smoking histories have been collected prospectively. In most epidemiological studies, smoking histories are collected retrospectively, after diagnosis, so the smoking histories are difficult to validate.

It should be emphasised that the comparisons in Table 39 showing excess risk are comparisons made within the cohort. The *Health Watch* cohort, as a whole, had a significantly reduced rate of lung cancer incidence compared with the general male population (Table 15).

Table 39: Lung cancer incidence (ICD-10 C33-C34) among men by smoking category, adjusted for age and calendar period of follow-up, compared to those who never smoked

Smoking Category	Person-Years	Lung Cancer	RIR	95% C.I.
Never smoked	164,004	21		
1-19 / day	28,041	34	**11.95**	**6.93 -20.61**
20-29 / day	30,036	82	**24.50**	**15.15 -39.63**
30+ / day	16,930	75	**38.91**	**23.95 -63.22**
Ex-smoker	210,863	198	**5.31**	**3.39 - 8.33**
Pipe/cigar only	2,754	<6	-	**2.49 -27.99**

Test for heterogeneity P<0.0001 Test for trend P<0.0001

Table 40 shows the association between smoking and lung cancer mortality for men. Here the trend was similar to that of lung cancer incidence but the point estimates of relative risk, which are greater than those for lung cancer incidence, were less reliable because the baseline comparison group of non-smokers contained only 15 deaths.

Table 40: Lung cancer mortality (ICD-10 C33-C34) among men by smoking category, adjusted for age and calendar period of follow-up, compared to those who never smoked

Smoking Category	Person-Years	Lung Cancer Deaths	RMR	95 % C.I.
Never smoked	185,144	15		
1-19 / day	31,598	34	**17.28**	**9.40 - 31.75**
20-29 / day	33,396	86	**38.42**	**22.16 - 66.61**
30+ / day	18,685	71	**55.51**	**31.75 - 97.07**
Ex-smoker	234,949	168	**6.34**	**3.74 - 10.75**
Pipe/cigar only	3,104	<6	-	**3.43 - 41.02**

Test for heterogeneity P<0.0001 Test for trend P<0.0001

5.1.5. Smoking and Bladder Cancer (ICD-10 C67)

An analysis was performed on the association between bladder cancer and smoking by smoking category. The results are shown in Table 41.

There was a strong and statistically significant trend of increased bladder cancer incidence with increasing tobacco use. The estimated relative risk in the category of smoking 1-19 or more cigarettes per day was twice that of those who have never smoked. The remaining categories of smoking all showed an excess risk of bladder cancer, up to almost six times more for those who smoked more 30 or more cigarettes per day, compared to those who have never smoked. Bladder cancer risk in pipe and cigar only smokers also showed increased risk compared to those who never smoked but there were fewer than six cases in this category and the confidence intervals were wide.

Table 41: Bladder cancer incidence (ICD-10 C67) by smoking category, adjusted for age and calendar period of follow-up, compared to those who never smoked

Smoking Category	Person-Years	Bladder Cancer	RIR	95% C.I.
Never smoked	164,004	20		
1-19 / day	28,041	6	2.24	0.90 - 5.59
20-29 / day	30,036	13	**4.07**	**2.02 - 8.21**
30+ / day	16,930	11	**5.95**	**2.84 -12.45**
Ex-smoker	210,863	80	**2.22**	**1.36 - 3.63**
Pipe/cigar only	2,754	<6	-	**2.56 -29.09**

Test for heterogeneity P<0.0001 Test for trend P<0.0001

5.1.6. Deaths Attributable to Smoking among Men in the Cohort

Health Watch cannot identify which individual deaths are caused by smoking but can provide an indication of the numbers of premature deaths attributable to the smoking habit. The effect is so critical to the future health of those in the cohort, that even crude figures are felt to be worth publishing (Figure 3 and Figure 4).

NB note the difference in scale between Figure 3 and Figure 4.

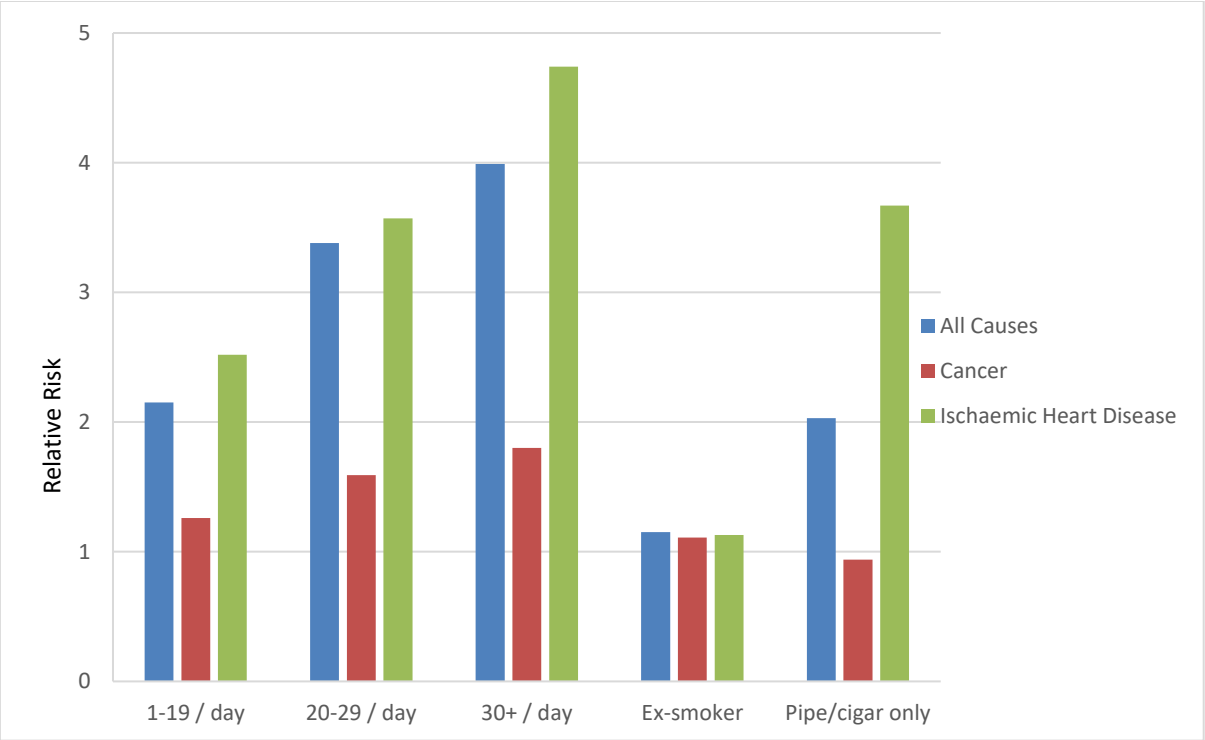

Figure 3: Relative risk of dying from any cause, of cancer, or of ischaemic heart disease among men for different smoking categories, compared to those who never smoked, adjusted for age and calendar year.

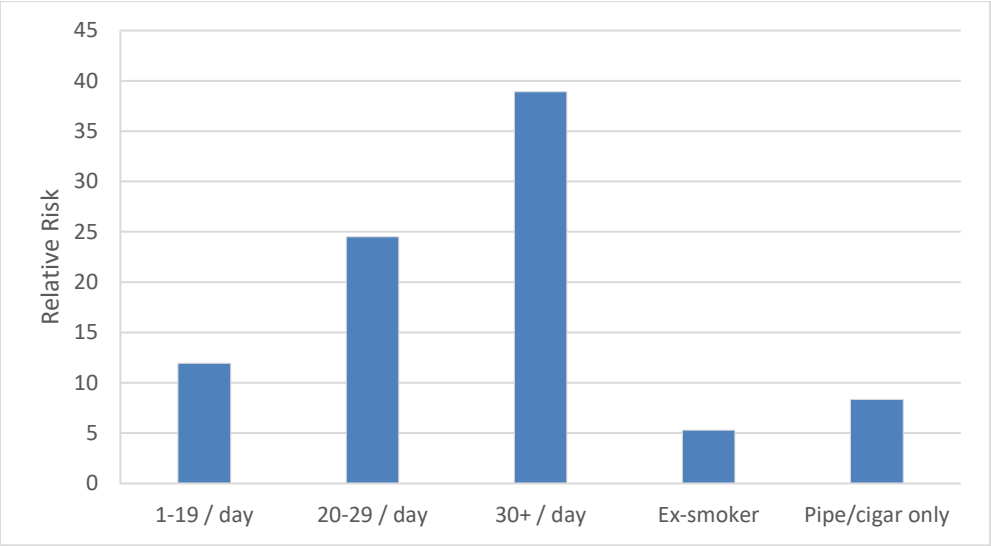

Figure 4: Relative risk of dying from lung cancer among men for different smoking categories compared to those who never smoked, adjusted for age and calendar year.

The effect of smoking on health risks for members of *Health Watch* is demonstrated in the results for lung cancer and ischaemic heart disease, specific causes of death which can be attributed to smoking. It is likely that other smoking-related diseases are also occurring in the cohort, just as they are in the Australian population as a whole. Crude analyses[2] of the results indicate that smoking may have caused about 48% of the ischaemic heart disease deaths, i.e. about 290 men in the cohort have died of heart attacks over the past 38 years due to smoking. Smoking accounts for nearly all lung cancers in the cohort but many other cancers are smoking-related as well.

Altogether it is estimated that smoking has been a contributing factor to about 49% of all male cancer deaths in the cohort, i.e., about 700 men. Combining all-causes of death, it is estimated that smoking has played a part in the deaths of about 1470 men, or 43% of the 3,419 deaths that have occurred in the 'ever smoker' group of the *Health Watch* cohort.

5.1.7. Effects of Quitting

Men who gave up smoking had better outcomes than those who continued to smoke. The effects of quitting are of interest to those in the cohort who have quit, and to those who might be encouraged to do so. The benefit of quitting smoking on mortality and cancer incidence can clearly be seen in the *Health Watch* cohort.

The RMR for deaths from all-causes was about 15% higher in ex-smokers compared with those who have never smoked (RMR 1.15, 95% C.I. 1.07-1.23) and was similar to the results produced in previous reports.(23, 28) In the case of death from ischaemic heart disease, the

[2] The estimates of excess deaths were computed by comparing the actual numbers of deaths with the number expected if the ever-smokers had the same mortality rate as never-smokers. The expected numbers were derived by multiplying the rates for never-smokers by number of person-years of follow-up in all the smoking categories combined. These were not age standardised.

RMR in ex-smokers was similar to that of never smokers (RMR 1.13, 95% C.I. 0.95-1.36), and was less than one-half of the risk relative to those who continued to smoke 1-19 cigarettes per day and much less than those who smoked more. The risk of dying from ischaemic heart disease in ex-smokers was also greatly reduced in the 15th Report (RMR 1.12, 95% C.I. 0.91-1.36).(28)

For all cancer deaths combined, the excess risk in ex-smokers was higher compared to those who have never smoked (RMR 1.26, 95% C.I. 1.12-1.42) and was the same as that reported in the 15th Report (RMR 1.29, 95% C.I. 1.12-1.48).(28)

Lung cancer mortality risk in ex-smokers remained higher compared to the risk in those who have never smoked (RMR 6.34, 95% C.I. 3.74-10.75). Whilst the risk was higher in ex-smokers, this risk was nearly a third of that compared to those who continued to smoke 1-19 cigarettes per day. Lung cancer incidence risk in ex-smokers also remained higher compared to those who have never smoked (RMR 5.31, 95% C.I. 3.39-8.33) but less than half of the risk in those who continued to smoke 1-19 cigarettes per day.

These data showed a slightly lower risk than that reported previously for all-cause mortality, all cancer mortality and lung cancer incidence among ex-smokers when compared to never smokers. Other studies have shown that the risk of lung cancer in men and women declines as the time since quitting increases.(55, 56, 57) There were slight reductions in IHD mortality and lung cancer mortality compared to the rates reported previously.

5.2. Alcohol Consumption among Men

The effects of alcohol consumption on mortality risk produces a "U-shaped" or “J-shaped” curve, as shown in Figure 5. This illustrates how low to moderate drinking results in a reduced risk of all-cause mortality compared to heavier drinking. As alcohol consumption increases, so does the risk of cancer and mortality. Because many important causes of death from alcohol are also affected by smoking, adjustment has been made in the analysis to allow for the influence of smoking.

Table 42 shows the relationship between drinking alcohol and death from all-causes compared to two different reference groups: 1-7 drinks per week and total abstainers. The comparison group used drastically alters the risk of mortality and the apparent protective effect of alcohol consumption. It has been found previously that the protective effects of alcohol disappear when comparison is made with occasional drinkers rather than total abstainers.(58) There were similar results in this analysis, when using the 1-7 drinks per week group as the reference rather than total abstainers. The protective effects of alcohol disappeared and the risk of mortality for low to moderate drinkers (8-21 drinks per week) was close to that of the reference group. Alternatively, consumption of 1-7 drinks appeared to be protective against mortality when total abstainers were used as the reference group. The total abstainers group also included ex-drinkers which may explain why they were at a significantly elevated risk of mortality when compared to occasional drinkers, i.e. somebody may be an ex-drinker or total abstainer because of an existing medical condition.

A significant increase in risk of all-cause mortality was observed in those who reported consuming more than 21 alcoholic drinks per week when either reference group was used. Figure 5 also demonstrates the difference in all-cause mortality risk when using the traditional comparative group of 0 drinks (blue line) and the 1-7 drinks per week (red line).

The protective effects of low to moderate drinking are displayed in the area below the 1 in the Relative Risk axis. This finding has been reported in other studies including a meta-analysis of 34 different studies. (59, 60, 61)

Additional analysis on alcohol consumption and cancer risk was performed for this report (Table 43). As with mortality, there was a clear association in increasing cancer incidence with increasing alcohol consumption compared to occasional drinkers (P<0.0001). There was a significantly increased risk in cancer incidence when alcohol consumption exceeded 21 drinks per week compared with occasional drinkers.

Table 42: All-cause mortality by alcohol category for men, adjusted for age, calendar year and smoking (ever vs never), compared to occasional drinkers (1-7 drinks per week) and total abstainers (0 drinks)

Number of drinks per week	Person-Years	Deaths	Compared to 1-7 drinks		Compared to abstainers	
			RMR	95 % C.I.	RMR	95 % C.I.
Nil	94,715	1,001	1.14	1.04 - 1.24		
1-7	136,843	1,000			**0.88**	**0.81 - 0.96**
8-21	159,764	1,131	1.07	0.98 - 1.17	0.94	0.86 - 1.03
22-35	58,838	594	**1.50**	**1.36 - 1.66**	**1.32**	**1.19 - 1.47**
36-49	30,155	369	**1.81**	**1.60 - 2.04**	**1.59**	**1.41 - 1.79**
50+	26,562	427	**2.28**	**2.04 - 2.56**	**2.01**	**1.79 - 2.25**

Ref group 1-7 drinks Test for heterogeneity P<0.0001 Test for trend P<0.0001
Ref group nil drinks Test for heterogeneity P<0.0001 Test for trend P<0.0001

Table 43: Cancer incidence by alcohol category for men, adjusted for age, calendar year and smoking (ever vs never), compared to occasional drinkers (1-7 drinks per week)

Number of drinks per week	Person-Years	Cancer	Compared to 1-7 drinks	
			RMR	95 % C.I.
Nil	85,020	917	1.02	0.94 - 1.12
1-7	121,743	1088		
8-21	142,025	1292	1.07	0.99 - 1.16
22-35	52,546	561	**1.22**	**1.10 - 1.35**
36-49	27,221	296	**1.26**	**1.11 - 1.43**
50+	24,073	323	**1.46**	**1.29 - 1.66**

Test for heterogeneity P<0.0001 Test for trend P<0.0001

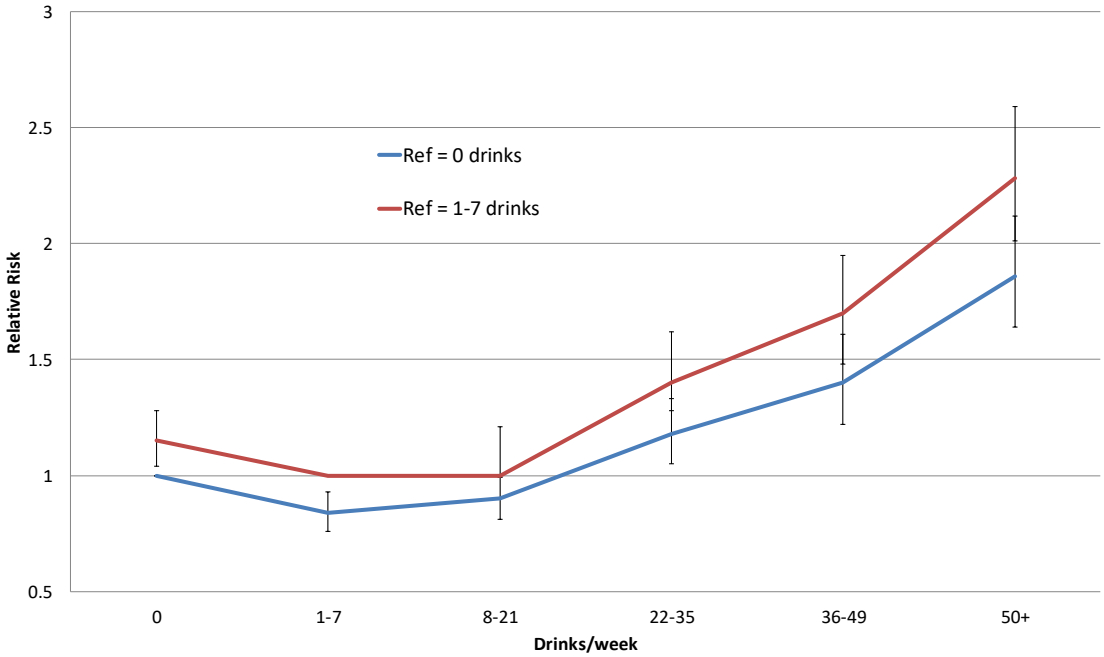

Figure 5: Relative risk of dying (all-cause mortality) for men with different levels of alcohol consumption, compared to those men who never drank alcohol and compared to occasional drinkers, adjusted for age, calendar year and smoking

Table 44 shows the association between alcohol consumption and mortality from ischaemic heart disease using 1-7 drinks per week as the reference group. This analysis was adjusted for tobacco use, which is an important contributing factor to heart disease. The results show a significant trend of increasing mortality from heart disease with increasing alcohol consumption (P=0.0038). There was a statistically elevated risk of mortality from ischaemic heart disease in those consuming more than 35 drinks per week compared with occasional drinkers. A protective effects of alcohol consumption and ischaemic heart disease was not observed in this analysis when using occasional drinkers as the reference group.

Analysis of the health risks from excess alcohol consumption should use occasional drinkers rather than total abstainers as the reference group as demonstrated in this report and the 15th *Health Watch* report.(28)

Table 44: Ischaemic heart disease mortality (ICD-10 I20-125) by alcohol category, adjusted for age, calendar year and smoking (ever vs never), compared to those who drink 1-7 alcoholic beverages per week.

Number of drinks/week	Person-Years	Deaths	RMR	95 % C.I.
Nil	94,715	197	1.19	0.97 - 1.45
Reference 1-7	136,843	184		
8-21	159,764	189	0.97	0.79 - 1.19
22-35	58,838	78	1.03	0.79 - 1.34
36-49	30,155	61	**1.54**	**1.15 - 2.07**
50+	26,562	71	**1.88**	**1.43 - 2.48**

Test for heterogeneity P<0.0001 Test for trend P=0.0038

Analyses by Tobacco Smoking and Alcohol Drinking

There is a clear pattern that increasing smoking category is associated with increasing risk of overall mortality, specifically ischaemic heart disease mortality, increasing risk of overall cancer incidence and mortality, and of bladder cancer incidence.

It is clear that all these risks are lower for ex-smokers than continuing smokers.

Moderate drinkers, less than 22 drinks per week, have a similar mortality and cancer risk compared to occasional drinkers (1-7 drinks per week). Heavier drinking, more than 21 drinks per week, is associated with increased overall cancer and mortality.

There was an increased mortality risk from heart disease in those male members of the cohort consuming more than 35 drinks per week compared with occasional drinkers. The opposite was observed in the 14th Health Watch Report where there was a significant reduction in risk for this group, however, the reference group for that report was total abstainers. This result emphasises the importance of using the correct or most appropriate reference group when doing internal comparisons. By using total abstainers as the reference group, the apparent protective effect of alcohol may be misleading.

6. SPECIFIC CANCERS

6.1. Mesothelioma (ICD-10 C45)

There were 63 mesotheliomas in the cohort. This is a statistically significant excess compared to the general population (SIR 1.59, 95% C.I. 1.22-2.04). Mesothelioma deaths before 1997 were coded under the ICD-9 scheme which did not have mesothelioma as a specific code. All cancers have been recoded from ICD-9 to ICD-10 by the cancer registries, but the deaths have not been re-coded on the NDI.

Mesothelioma risk is strongly related to asbestos exposure. Although the disease is more common in workers who have been heavily exposed, the exposure-response relations is not well documented and cases usually don't have a diagnosis of asbestosis before their diagnosis of mesothelioma. Smoking has not been found to be a risk factor for mesothelioma.(62, 63, 64)

Because mesothelioma is nearly always associated with a history of exposure to asbestos, every case should be regarded as important, irrespective of the statistical significance of the SIR. Asbestos insulation was used in refineries, particularly in the 1950's and 1960's and the findings of a persisting excess SIR for mesothelioma demonstrates the known long latency to develop this cancer, which is almost uniformly fatal.

6.2. Lung Cancer (ICD-10 C33-C34)

There were 20 cases of lung cancer among women. This rate was slightly higher than the general female population. The incidence of lung cancer among men in the *Health Watch* cohort is lower than in the general male population (SIR 0.84, 95% C.I. 0.76-0.93).

As shown in Table 15 on page 47, the incidence of laryngeal cancer was below that of the general male population (SIR 0.81, 95% C.I. 0.58-1.11). Incidence rates for cancer of the lip, oral cavity and pharynx was also lower than that of the reference population (SIR 0.80, 95% C.I. 0.67-0.94). Chronic obstructive pulmonary disease (COPD) was at least as strongly associated with smoking as was lung cancer. Indeed, these diseases (mainly chronic bronchitis and emphysema) are uncommon in non-smokers. The mortality rate from COPD was reduced in *Health Watch* (170 deaths vs 262 expected, SMR 0.65, 95% C.I. 0.55-0.75). These figures suggest that the low lung cancer rate in the *Health Watch* population is likely to be due to low average lifetime tobacco use compared with the general population.

A comparison of lung cancer incidence was made between refinery workers and all other workers, adjusted for age, calendar period and smoking. The relative risk was similar for the two groups (RIR 1.00, 95% C.I. 0.80-1.25). Similarly, little difference in lung cancer incidence was seen between maintenance workers and all other refinery workers (RIR 0.93, 95% C.I. 0.76-1.76).

6.3. Melanoma of the Skin (ICD-10 C43)

Melanoma was one of the commonest cancers in the *Health Watch* cohort, second only to prostate cancer in men and breast cancer in women. There were 26 cases of melanoma in women and this risk was similar to that of the general female population.

There were 552 melanoma cases in men, and the incidence of melanoma was raised relative to the general population (SIR 1.21, 95% C.I. 1.11-1.31). Melanoma mortality, however, was similar to that of the general Australian population (SMR 0.97, 95% C.I. 0.76-1.22). These findings may suggest a screening bias whereby more cases are detected earlier and were effectively treated. Table 45 shows that the melanoma incidence in men was elevated in most workplace types particularly in refinery and terminal workplaces where most men worked and this work is often performed outside involving potential sun exposure, a known risk factor for melanoma.

Table 45: Melanoma (ICD-10 C43) incidence in men by workplace type, adjusted for age and calendar period of follow-up, compared to the Australian population

Workplace Type	Person-Years	Observed	Expected	SIR	95% C.I.
Refinery	178,905	235	180.72	**1.30**	**1.14 - 1.48**
Terminal	174,516	228	183.92	**1.24**	**1.08 - 1.41**
Airport	17,003	25	18.93	1.32	0.85 - 1.95
Onshore production	61,135	45	53.95	0.83	0.61 - 1.12
Offshore Production	20,502	19	18.46	1.03	0.62 - 1.61
Total	452,628	552	456.31	**1.21**	**1.11 - 1.31**

The following three tables analyse melanoma incidence according to period of first employment, duration of employment, and lapse of time between first employment and diagnosis of melanoma. There was a significant trend of increasing melanoma incidence by period of first employment (P=0.03) with the highest rates in the pre 1954 category. The highest rate of melanoma incidence was in members of the cohort employed for the shortest period of time, 5-9 years, whilst those employed for 10-24 years had a lower risk of melanoma. The reason for this finding is not clear.

Table 46: Melanoma (ICD-10 C43) incidence among men by period of first employment, adjusted for age, calendar period of follow-up and ever/never smoker, compared to those employed after 1985

Period of first Employment	Person-Years	Melanoma	RIR	95% C.I.
Post 1985	80,647	59		
1975-84	174,640	160	1.09	0.80 - 1.49
1965-74	128,563	182	1.32	0.94 - 1.87
1955-64	47,903	101	1.52	0.99 - 2.32
Pre 1954	20,875	50	1.54	0.94 - 2.54

Test for heterogeneity P=0.2314 Test for trend P=0.0286

Table 47: Melanoma (ICD-10 C43) incidence in men by duration of employment, adjusted for age, calendar period of follow-up and ever/never smoker compared to those employed for 5-9 years

Duration of Employment	Person-Years	Melanoma	RIR	95% C.I.
5-9 Years	85,098	76		
10-15 Years	92,727	77	0.72	0.53 - 1.00
15-19 Years	83,490	81	**0.68**	**0.49 - 0.94**
20-24 Years	70,999	69	**0.58**	**0.41 - 0.81**
≥25 Years	120,132	249	0.93	0.70 - 1.24

Test for heterogeneity P=0.0006 Test for trend P=0.5679

Table 48: Melanoma (ICD-10 C43) incidence in men by time since first employment, adjusted for age, calendar period of follow-up and ever/never smoker compared to those first employed 5-9 years ago

Time Since First Employment	Person-Years	Melanoma	RIR	95% C.I.
5-9 Years	40,338	14		
10-15 Years	56,783	35	1.32	0.70 - 2.50
15-19 Years	65,058	47	1.16	0.61 - 2.22
20-24 Years	68,576	50	0.90	0.46 - 1.76
≥25 Years	221,868	406	1.20	0.62 - 2.32

Test for heterogeneity P=0.3441 Test for trend P=0.8327

The excess incidence of melanoma varied by the state of the work site, (see Table 49). Men who worked in Queensland had the highest incidence compared to national data, followed by those who worked in New South Wales. Those who worked in Victoria and South Australia had the lowest (numbers are very small in the Northern Territory and Tasmania). This suggests a link with sun exposure. It should be noted that some workers may not reside and have their melanoma registered in the same state as they work e.g., offshore workers.

Table 49: Melanoma (ICD-10 C43) incidence compared to national rates for men by state of last employment

State	Person-Years	Observed	Expected	SIR	95% C.I.
VIC	145,109	130	142.07	0.92	0.76 - 1.09
ACT	28	-	-	-	-
NSW	120,680	179	129.60	**1.38**	**1.19 - 1.60**
NT	2,804	<6	-	-	0.08 - 2.43
QLD	58,993	109	58.86	**1.85**	**1.52 - 2.23**
SA	52,490	49	52.15	0.94	0.70 - 1.24
TAS	4,077	6	4.73	1.27	0.47 - 2.76
WA	68,447	77	65.89	1.17	0.92 - 1.46
All states	452,628	552	456.31	**1.21**	**1.11 - 1.31**

However, because melanoma incidence varied by state, further analyses were undertaken using state-based rather than national comparison rates. These are presented in

Table **50** and show an elevated risk in Victoria, Queensland and New South Wales which was also observed in the previous two reports.(23, 28)

Table 50: Melanoma (ICD-10 C43) incidence compared to state specific rates for men by state of last employment

State	Person-Years	Observed	Expected	SIR	95% C.I.
VIC	145,109	130	105.80	**1.23**	**1.03 - 1.46**
NSW	120,680	179	133.39	**1.34**	**1.15 - 1.55**
QLD	58,993	109	82.82	**1.32**	**1.08 - 1.59**
WA	68,447	77	70.40	1.09	0.86 - 1.37
SA	52,490	49	40.35	1.21	0.90 - 1.61

6.4. Prostate Cancer (ICD-10 C61)

Prostate cancer was the most common cancer in men in the *Health Watch* cohort. There were 1,371 cases, up from 1,072 in the previous report.(23, 28) The incidence was elevated overall (SIR 1.12, 95% C.I. 1.06-1.18).

Prostate cancer mortality, however, was the same as that for the general population (SMR 0.95, 95% C.I. 0.82-1.08). These findings may suggest that members of the cohort were screened for prostate cancer at a greater rate than the general population and may indicate a screening bias whereby more cases are detected earlier, but at a stage when treatment was likely to have a more successful outcome.

6.5. Bladder Cancer (ICD-10 C67)

There were 133 bladder cancers in men which was close to the expected number, compared to the general male population (SIR 1.01, 95% C.I. 0.85-1.20). The non-statistically significant excesses of bladder cancer seen in the 12th *Health Watch* report (SIR 1.07, 95% C.I. 0.89-1.50) (7) and the 13th Report (SIR 1.11, 95% C.I. 0.85-1.43) was no longer evident. This most recent analysis has shown, however, that the risk of bladder cancer among drivers remains elevated (SIR 1.29, 95% C.I. 0.83-1.90).

6.6. Kidney Cancer (ICD-10 C64-C66, C68)

There were 131 cases of kidney cancer among men in the *Health Watch* cohort. This analysis, together with the last analysis has shown that the estimated risk of this cancer has attenuated compared to the 12th and 13th reports, (7, 9) suggesting that the risk is now similar to that in the general population (SIR 1.06, 95% C.I. 0.88-1.26). Drivers were again the exception with an increased risk of kidney cancer (SIR 1.40, 95% C.I. 0.92-2.05). This risk was slightly higher compared to the 15th report (SIR 1.28, 95% C.I. 0.79-1.96).(28)

6.7. Leukaemia (ICD-10 C91-C95)

There were 98 leukaemia cases found in men, 24 more than were identified in the last report. The risk of leukaemia among *Health Watch* men is now lower than that of the general population (SIR 0.77, 95% C.I. 0.62-0.94).

The rates for individual leukaemia subtypes, are close to, or less than, the expected rates. Table 51 shows that there was no significant excess of leukaemia incidence in any workplace type, all SIR point estimates were below one.

Table 51: Leukaemia (ICD-10 C91-C95) incidence among men by workplace type, adjusted for age and calendar period of follow-up, compared to the Australian population

Workplace	Person-Years	Observed	Expected	SIR	95% C.I.
Refinery	178,905	42	51.19	0.82	0.59 - 1.11
Terminal	174,516	42	52.71	0.80	0.57 - 1.08
Airport	17,003	<6	-	-	0.11 - 1.60
Onshore production	61,135	8	13.68	0.58	0.25 - 1.15
Offshore Production	20,502	<6	-	-	0.24 - 2.25
Total	452,628	99	127.67	**0.78**	**0.63 - 0.94**

6.7.1. Leukaemia by measures of duration

The following three tables analyse leukaemia incidence according to period of first employment, categories of duration of employment, and lapse of time between first employment and diagnosis of leukaemia. There was no evidence of a trend in the relative incidence rate in any of these analyses.

Table 52: Leukaemia (ICD-10 C91-C95) incidence by period of first employment, adjusted for age, calendar period of follow-up and smoking (ever vs never), compared to those employed after 1985

Period of first Employment	Person-Years	Leukaemia	RIR	95% C.I.
Post 1985	80,647	6		
1975-84	174,640	28	1.53	0.61 - 3.81
1965-74	128,563	34	1.53	0.57 - 4.08
1955-64	47,903	20	1.36	0.45 - 4.18
Pre 1954	20,875	11	1.38	0.40 - 4.77

Test for heterogeneity P=0.8869 Test for trend P=0.9573

Table 53: Leukaemia (ICD-10 C91-C95) incidence in men by duration of employment, adjusted for age, calendar period of follow-up and smoking (ever vs never), compared to those employed for 5-9 years

Duration of Employment	Person-Years	Leukaemia	RIR	95% C.I.
5-9 Years	85,098	10		
10-15 Years	92,727	14	0.99	0.43 - 2.25
15-19 Years	83,490	18	1.08	0.49 - 2.41
20-24 Years	70,999	16	**0.94**	**0.41 - 2.15**
≥25 Years	120,132	40	0.97	0.45 - 2.09

Test for heterogeneity P=0.9952 Test for trend P=0.8595

Table 54: Leukaemia (ICD-10 C91-C95) incidence in men by time since first employment, adjusted for age, calendar period of follow-up and smoking (ever vs never), compared to those first employed 5-9 years ago

Time since first Employment	Person-Years	Leukaemia	RIR	95% C.I.
5-9 Years	40,338	<6		
10-15 Years	56,783	6	1.33	0.32 - 5.43
15-19 Years	65,058	<6	-	0.19 - 3.89
20-24 Years	68,576	11	1.47	0.34 - 6.31
≥25 Years	221,868	74	1.47	0.34 - 6.35

Test for heterogeneity P=0.8424 Test for trend P=0.5282

6.8. Multiple Myeloma (ICD-10 C90)

There were 66 multiple myeloma cases in men in the cohort (SIR 1.10, 95% C.I. 0.85-1.40). As shown in Table 55, the incidence rate for multiple myeloma was slightly elevated amongst terminal workers and slightly elevated overall (Table 15).

Table 55: Multiple myeloma (ICD-10 C90) incidence among men by workplace type, adjusted for age and calendar period of follow-up, compared to the Australian population

Workplace	Person-Years	Observed	Expected	SIR	95% C.I.
Refinery	178,905	28	23.97	1.17	0.78 - 1.69
Terminal	174,516	30	24.78	1.21	0.82 - 1.73
Airport	17,003	-	-	-	-
Onshore production	61,135	7	6.43	1.09	0.44 - 2.24
Offshore Production	20,502	<6	-	-	0.01 - 2.57
Total	452,628	66	59.96	1.10	0.85 - 1.40

Comments on Specific Cancers in Men

Mesotheliomas, melanoma of the skin and prostate cancer all occurred in excess among men in the Health Watch cohort compared to national rates.

Melanoma incidence did not increase with increasing duration of employment, time since first employment or time period of first employment. Melanoma incidence was compared to the corresponding state rates, and three specific states exhibited considerably higher rates. However, the mortality rate for melanoma was similar to the Australian rate.

There was a reduced incidence of lung cancer, liver cancer and cancers of the lip, oral cavity and pharynx and of deaths from COPD which is probably a result of less tobacco consumption by members of the cohort than by the general Australian population.

Bladder and kidney cancers in the cohort remained similar to the general population, as does multiple myeloma. Prostate cancer incidence in the cohort was statistically significantly higher than in the general population, however prostate cancer mortality was similar to that of the general population.

There was a significant decrease in overall leukaemia and no excess risks for any of the leukaemia subtypes.

7. DISCUSSION

7.1. Strengths and Weaknesses of the Study

7.1.1. Individual Interview Data

A major strength of *Health Watch* is that there is at least one personal interview record for every person in the cohort. The interview included information about the jobs undertaken by the participants. Furthermore, it collected comprehensive information regarding the participants' smoking habits and alcohol consumption, although it is important to note that some of this data was collected many years ago, and smoking and drinking rates may have fluctuated since then.

7.1.2. High Participation Rate

Participation in *Health Watch* was based on voluntary enrolment. The possibility of volunteer bias arises when individuals who are motivated to participate differ in terms of their health status compared to those who choose not to participate. However, this bias is unlikely in the case of *Health Watch* due to the active recruitment process and the remarkably high rates of participation. Site rolls were provided to the survey interviewers, and all employees were approached and invited to participate. Refusal to participate was uncommon, and the reason for the missing employees was, in most cases, difficulty in locating them through temporary absence such as shift work or annual leave. The first two surveys recorded exceptionally high participation rates, reaching 93%, which greatly diminishes the likelihood of volunteer bias. The participation rates were lower in the Third and Fourth surveys (estimated at 84% and 73% respectively). The latter resulted in a lack of recruits to the cohort in the Fourth Survey from offshore production,(7) although this did not significantly alter the composition of the cohort: 4.0% of the cohort were in the offshore production sector, prior to the Fourth Survey and 3.7% afterwards.

7.1.3. Volunteer Bias

Another potential source of volunteer bias arises from the possibility of employees choosing to participate in *Health Watch* after developing an illness. In other words, individuals who initially declined to participate in a *Health Watch* survey may later volunteer to take part in a subsequent survey after being diagnosed with a disease. This scenario could introduce an upward bias leading to an overestimation, of the mortality rate. However, since the observed mortality rates for major disease categories and most individual cancers were lower than expected, it is unlikely that this factor has resulted in any misleading findings. It is important to note that joining the *Health Watch* cohort after being diagnosed with cancer does not impact the cancer analysis. This is because the follow-up period does not commence until the individual becomes a cohort member, which occurs either during the interview or after five years in the industry, whichever is later. Cancers occurring before this point are excluded from the analysis.

7.1.4. Unverified Date of Employment

One potential limitation of the study is the reliance on members of the cohort to provide the date of their first employment in the industry at the time of interview. This could introduce some uncertainty and potential errors when analysing variables related to time, such as

period of employment, duration of employment and time elapsed since employment. Errors resulting from the imperfect recollection of the year of hire are likely to be random in nature, meaning they are unlikely to introduce bias into the analysis. Additionally, it is reasonable to assume that such errors, if present, would have minimal impact on the overall analysis, considering the substantial size of the time-related categories (e.g., period of employment categories are pre-1954, 1955-64, 1965-74, 1975-84 and post-1985). Therefore, any potential inaccuracies resulting from imperfect recall of the year of hire are expected to have a negligible effect relative to the larger time-related categories used in the study.

Date of termination of employment was obtained from participating companies records however, information was not always complete. An audit of those classified as still employed by participating companies disclosed that many were no longer employed.(7) Following a further check of company employment records and other follow-up measures, the errors from this source were minimised.(7) In recent years, company update information has not always been readily forthcoming. A proportion of employment histories may not be up to date for those whose employing companies did not provide complete company update information and for those employees who did not return the latest Health Letter in 2018.

7.1.5. Complete Cancer Identification

Identification of cancer is a major strength of the study as cancer registration is mandatory in all Australian states and territories, and registration is virtually complete. However, it is important to note that complete matching of individual's data cannot be guaranteed because of privacy constraints that prevent the release of uncertain matches. Additionally, challenges have arisen in reconciling information from the ACD maintained by the AIHW with data provided by state and territory cancer registries which supply the information to it.(65) This is discussed in Section 2.4.4 (page 29), but is unlikely to have much impact and the study methods take these issues into account.

7.2. The Healthy Worker Effect

Figure 6 presents the SMRs and SIRs for men in *Health Watch* over time. This analysis was compiled with all new data obtained from the most recent linkage with the cancer and death registries and can only be compared to figures from the 14th and 15th *Health Watch* reports. Reports prior to the 14th *Health Watch* report simply added the extra years of data rather than re-analysing the entire cohort period with the new available data.

A common finding with the *healthy worker effect* is that it decreases as the cohort ages, that is, the SMR tends to increase with time, approaching the general mortality rates of the population.(66) This tendency is becoming evident for men shown by the trend lines in Figure 6. Studies have reported the *healthy worker effect* to last for as few as 5 years or more than 30 years. (47, 48, 49, 66)

The *healthy worker effect* was initially stark in *Health Watch* with SMRs for workers in the industry lower than many reported from other occupational cohorts.(67) This may be partly because workers must serve for five years in the industry before entering the cohort. This is a longer qualifying period than for many other occupational cohorts. Research suggests that a higher proportion of overall sitting time or an inactive lifestyle are positively associated with increased overall mortality (68, 69). Many jobs recorded in this cohort are largely

active with minimal sedentary periods which also support the strong *healthy worker effect* in the petroleum industry.
Several studies have shown that the *healthy worker effect* is less pronounced for cancer incidence than for mortality. Cancer is primarily a disease of old age and, as such, the *healthy worker effect* may be less likely to have an impact i.e. any selection effects may have "worn off" with time as the cohort ages.(66)

The SMRs and SIRs for women were based on very few cases, particularly in the earlier reports. No SIRs for women presented in previous reports have been significantly different to that of the general population but this may be a result of the small numbers.

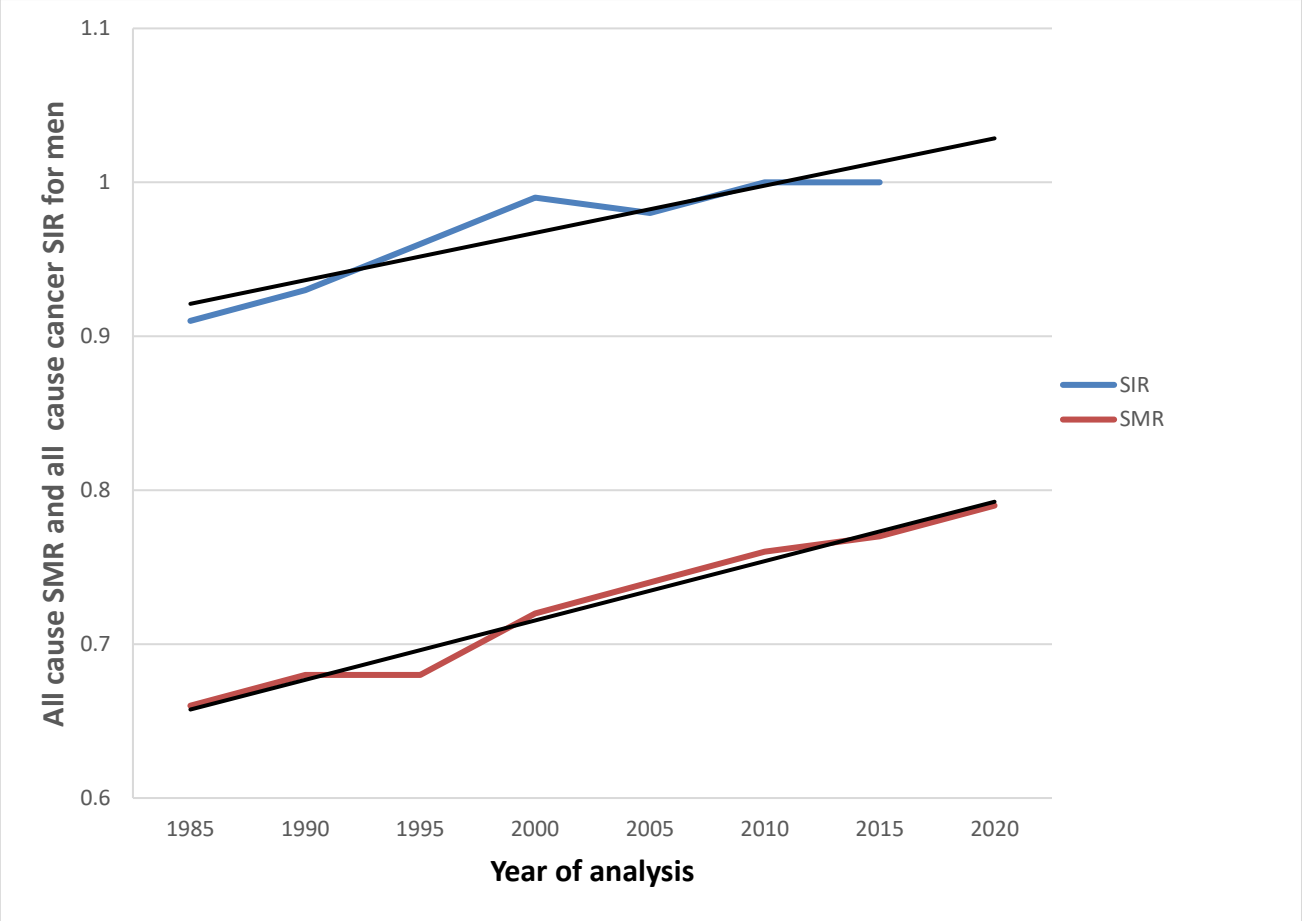

Figure 6: All Cause SMR, all cancer SIRs for men in *Health Watch*, plotted at yearly intervals

7.3. Mesothelioma and other Asbestos-related Conditions

Twelve cohort members have died from asbestosis. In addition, the occurrence of 63 cases and the significantly increased risk of mesothelioma was an indication of past asbestos exposure and is consistent with the findings of other studies in oil refinery workers.(70, 71, 72, 73) Asbestos insulation was commonly utilised in refineries, especially during the 1950s and 1960s. There is a long latency period between initial exposure to asbestos and occurrence of this type of cancer. (74, 75)

There is now a significantly heightened understanding of the dangers associated with asbestos and consequently strict rules have been implemented to minimise the risk of

asbestos exposure. Nevertheless, mesotheliomas can occur after quite low exposures, and it is important that any potential sources of exposure be identified and removed or controlled.

7.4. Lung Cancer

Despite the fact that the prevalence of smoking in the cohort, as measured when the data was collected, was only slightly lower than that of the Australian male population, the relatively low incidence of lung cancer may seem surprising (see 5.1.1). However, lung cancer risk is also predicted by factors such as the number of cigarettes smoked, age at starting, age at quitting and tar content.(57, 76) Thus, although the prevalence of current smokers was similar in the *Health Watch* cohort and the general male population, it is quite possible that the average lifetime tobacco consumption in the *Health Watch* cohort is much less. Among younger people (under 30) the smoking rates in *Health Watch* were much lower, about half of that in the general population. A possible scenario could be that, on average, *Health Watch* smokers tend to smoke fewer cigarettes than other Australian men. Another factor could be that individuals in the cohort who quit smoking did so at a younger age compared to the general population. Additionally, it is also possible that a greater number of individuals have quit smoking since the data were collected, which could contribute to the lower incidence of lung cancer. (Table 33).

Additional support for the notion of comparatively lower lifetime tobacco use in the *Health Watch* cohort can be found in analyses relating to other diseases strongly associated with smoking such as cancers of the lip, oral cavity and pharynx, laryngeal cancer and chronic obstructive pulmonary diseases. These analyses consistently indicate lower rates of these conditions compared to the general population. These figures suggest that the low lung cancer rate in the *Health Watch* population is likely to be due to low average lifetime tobacco use compared with the general population.

The presence of 63 cases of mesothelioma within the *Health Watch* cohort, as well as in other studies involving oil refinery workers, raises the possibility of an increased asbestos-related lung cancer risk. Several studies within the petroleum industry have identified a simultaneous increase of mesothelioma incidence and low mortality rates from lung cancer (77, 78, 79, 80) However, not all studies have been able to replicate these findings.(81, 82) While reduced lung cancer risk in some studies may be attributed to lower smoking rates, many studies lack comprehensive smoking data. Considering the overall low occurrence of lung cancer in *Health Watch,* it is likely that any asbestos-related lung cancers among refinery workers would be limited in number.(71, 77, 83)

To explore this hypothesis, an investigation was conducted by comparing the incidence of lung cancer between refinery workers and the remaining individuals of the *Health Watch* cohort. This analysis was conducted because asbestos exposure was more probable in refinery settings compared to other work environments. Furthermore, within the group of refinery workers, a comparison was made between maintenance workers and non-maintenance workers to assess any differences in lung cancer rates. This approach was chosen because maintenance workers were more likely to have contact with asbestos compared to other occupational groups. An advantage of such an analysis in this cohort is that smoking data, based on individual histories obtained prospectively from every participant in the cohort, are available. The analyses showed that after adjusting for smoking status, there was no difference in lung cancer incidence among refinery workers compared to non-refinery workers (SIR 1.00, 95% C.I. 0.80-1.25); and within refineries there was a similar risk for lung cancer incidence in maintenance workers compared to non-maintenance

workers (SIR 1.16, 95% C.I. 0.76-1.76). It should be noted, however, that these analyses were based on small numbers of lung cancers.

7.5. Melanoma

Table 56 presents the SIRs and the cumulative incidence of melanoma among men in *Health Watch*. The analysis examined the state of the cohort every three years since 1987 against data from the relevant time period. The risk of melanoma among men has remained significantly higher than that of comparable Australian national rates. As the number of cases increased the confidence intervals become narrower as shown in Table 56.

Table 49 (page 74) shows that melanoma rates, when compared to national data, vary with state, very likely due to differences in sun exposure in different geographical parts of Australia. It is of interest to note that although melanoma incidence was elevated in the cohort, melanoma mortality was the same as that for the general population (SMR 0.97, 95% C.I. 0.76-1.22). These findings may suggest that members of the cohort detect their melanoma earlier or are screened more often for melanoma or that they are diagnosed earlier for some other reason and can be treated more effectively than the general population.

Table 56: Melanoma (ICD-10 C43) risk over time for men in the *Health Watch* cohort

Melanoma	**1987**	**1990**	**1993**	**1996**	**1999**	**2002**	**2008**	**2012**	**2016**
Cases	24	48	82	122	176	224	338	438	552
SIR	1.25	1.26	**1.34**	**1.34**	**1.38**	**1.31**	**1.23**	**1.22**	**1.21**
95 % C.I.	0.80 - 1.86	0.93 - 1.67	**1.07 - 1.67**	**1.12 - 1.60**	**1.19 - 1.60**	**1.15 - 1.50**	**1.10 - 1.36**	**1.11 - 1.34**	**1.11 - 1.31**

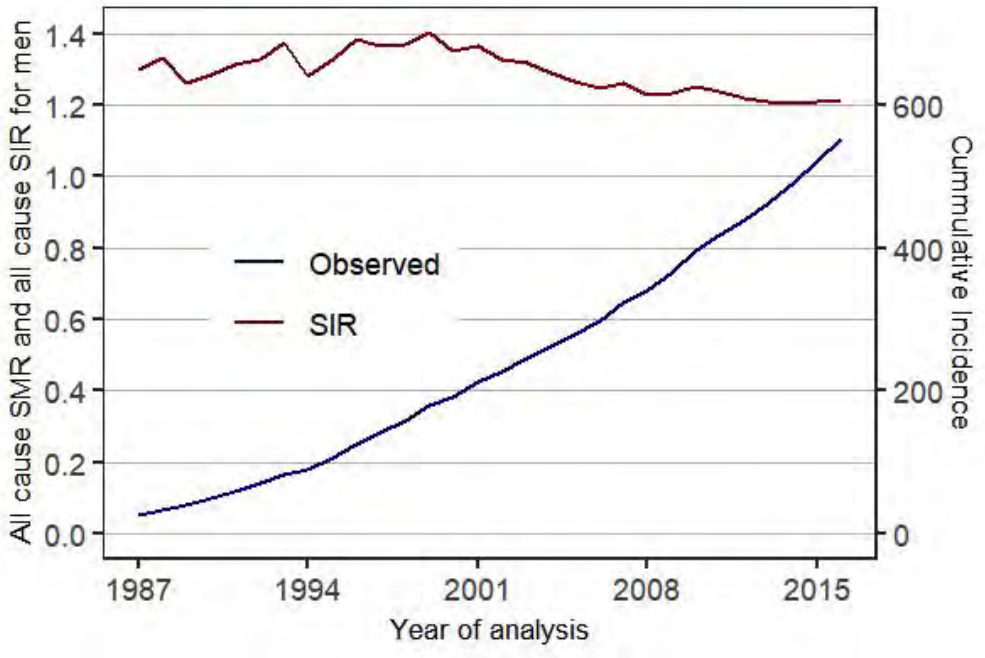

Figure 7 SIRs and cumulative melanoma incidence in men from 1987-2016

A statistically significant excess of melanoma mortality has been reported in UK refinery workers (84, 85) and a non-significant excess in USA refinery workers.(86) The highest SMR for melanoma was reported for Imperial Oil Limited (IOL) employees at upstream operations in Canada: SMR 6.00, 95% C.I. 2.19-13.06.(78) The only other cancer incidence study in the industry (an IOL cohort which overlapped with that reported previously), showed an excess of cases of melanoma in both men (SIR 1.25, 95% C.I. 0.82-1.83), and women (SIR 1.46, 95% C.I. 0.83-1.27).(73)

Apart from the well-established association with exposure to solar radiation, melanoma has a tendency to occur in higher socioeconomic groups.(87) There is no reason to suspect socioeconomic status to be of special significance in this cohort, which has mostly excluded senior management. Companies may offer education and awareness programs to promote the use of sunscreen, protective clothing, and encourage regular skin checks to detect early signs of melanoma, which ultimately, leads to improved melanoma survival rates.

7.6. Bladder Cancer

Bladder cancer was found in excess in the 11th Report (SIR 1.37, 95% C.I. 1.00-1.83).(29) Since this time, the excess risk has declined and is no longer elevated. The previous report (SIR 0.88, 95% C.I. 0.61-1.23) and the current results show that bladder cancer risk is similar to that of the general population (SIR 1.01, 95% C.I. 0.85-1.20).

Bladder cancer incidence was again found to be somewhat elevated among drivers compared with office-only workers, however, the number of cases was small, and the confidence intervals were wide (RIR 1.49, 95% C.I. 0.81-2.74).

7.7. Leukaemia

Leukaemia has been a cancer of special concern in this industry because of its association with benzene exposure. Table 57 and Figure 8 show the reduction in leukaemia SIR over time. There was more than a 2-fold excess of leukaemia in 1987 and 1990 (3, 4, 5, 30) The incidence of leukaemia is now significantly lower in the cohort compared with the general population. Moreover, internal analysis within the cohort showed no significant trend in leukaemia incidence with duration of employment. This finding is not unexpected, since "leukaemia" is not a single disease, but a composite of leukaemia types which are in fact different disease entities. Of these, only acute myeloid leukaemia is commonly associated with benzene exposure, although there are some data suggesting that CLL may be associated with benzene exposure.(16, 88, 89)

Several case-control studies have been conducted in the industry providing valuable insights into the association between occupational exposures and cancer risks A study involving petroleum marketing and distribution workers in the UK, found some indication of a relationship between exposure to benzene and myeloid leukaemia, particularly acute myeloid leukaemia.(34) Similarly, a case-control study nested within the Canadian cohort in 1996 demonstrated a link between duration of exposure to benzene and leukaemia risk, although the study had limited statistical power to detect an association between increasing benzene exposure and leukaemia risk.(90) In contrast, a nested case-control study within the *Health Watch* cohort revealed a strong association between increasing benzene exposure and leukaemia risk.(13, 14, 16)

Benzene is now widely recognised as a haematotoxin and leukaemogen, particularly at relatively high levels of exposure (91, 92, 93). In 2017/8, the International Agency for Research on Cancer (IARC) reaffirmed the association between benzene and acute myeloid leukaemia (AML) in humans. Additionally, the IARC indicated that benzene is likely linked to other leukaemia subtypes and lymphoid neoplasms.(94, 95) However, different interpretations exist regarding the consistency of the relationship between benzene and lymphoid neoplasms in various meta-analyses.(96, 97, 98, 99)

A review using meta-regression to examine dose-response relationships suggested that benzene exposure less than 50 ppm-years resulted in a statistically significantly elevated risk of all leukaemia in aggregate.(100) But few quantitative studies have examined risks between specific leukaemia subtypes and exposure to lower concentrations of benzene.(88)

Collectively, a combination of enhanced workplace practices, regulatory measures, early detection efforts, workforce changes, and health promotion initiatives may have potentially contributed to the reduction of leukaemia and other occupational cancer risks.

Table 57: Leukaemia incidence for men reported over time in the *Health Watch* cohort

Leukaemia	**1987**	**1990**	**1993**	**1996**	**1999**	**2002**	**2008**	**2012**	**2016**
Observed	9	16	18	24	30	37	56	74	98
SIR	2.07	**1.90**	1.30	1.16	1.01	0.90	0.80	0.80	0.77
95% C.I.	0.94 - 3.92	**1.09 - 3.09**	0.77 - 2.06	0.74 - 1.72	0.68 - 1.45	0.64 - 1.24	0.61 - 1.04	0.63 - 1.00	0.62 -0.94

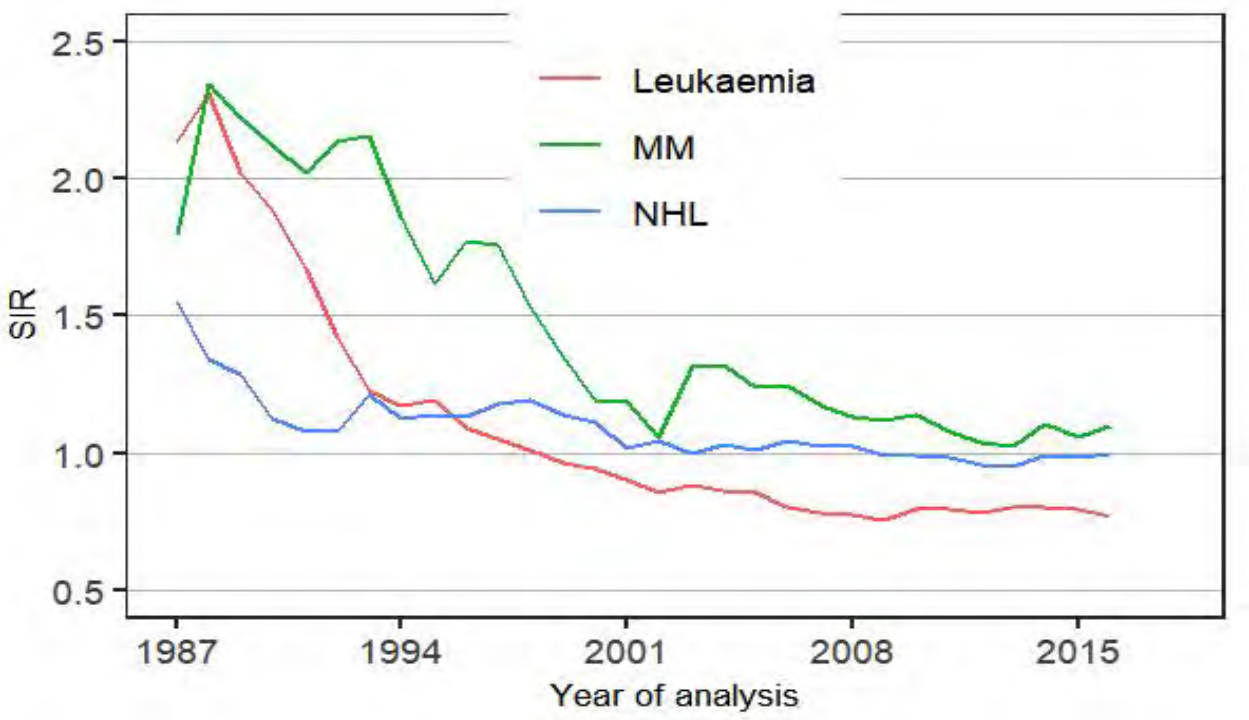

Figure 8: SIRs for leukaemia, NHL and MM in men from 1987 - 2016

A combined study of three petroleum industry case-control studies, funded by CONCAWE, yielded interesting findings regarding the association between benzene exposure and various

leukaemia subtypes. The results did not provide convincing evidence for an association between benzene exposure and AML or other leukaemia subtypes. However, the study did identify a potential association between benzene exposure and MDS (22) which is also a risk factor for leukaema. These findings emphasise the complexity of the relationship between benzene exposure and specific leukemia subtypes, highlighting the need for further research in this area.

7.8. Other Lympho-Haematopoietic Cancers in Men

The *Health Watch* study has shown particular interest in investigating other blood and bone marrow cancers. As the cohort has aged and more cases have emerged, non-Hodgkin lymphoma (NHL), multiple myeloma (MM), and leukaemia have been analysed separately. Table 58 presents the re-analyses of NHL and MM incidence at various time points. This shows that the SIRs for both NHL and MM have been declining steadily over the years. There was a statistically elevated rate of MM in 1993, however, the number of cases in the earlier years were small. The steady decline in rates is also shown in Figure 8.

Excess rates of MM have been reported in some studies but not others and there has been much debate in the literature about whether exposure to benzene is associated with increased risk of MM.(96, 101, 102, 103, 104)

Table 58: NHL (ICD-10 C82-C85, C96) and MM (ICD-10 C90) incidence for men in the *Health Watch* cohort from 1987 to 2016

		1987	**1990**	**1993**	**1996**	**1999**	**2002**	**2008**	**2012**	**2016**
NHL	Cases	10	14	24	34	49	61	98	125	164
	SIR	1.61	1.14	1.15	1.08	1.11	1.02	1.00	0.96	1.01
	95% C.I.	0.77-2.96	0.63-1.92	0.74-1.72	0.75-1.51	0.82-1.47	0.78-1.32	0.81-1.22	0.80-1.14	0.86-1.18
MM	Cases	<6	7	12	15	17	19	36	46	66
	SIR	-	2.12	**2.16**	1.78	1.35	1.06	1.14	1.05	1.10
	95% C.I.	0.37-5.25	0.85-4.37	**1.12-3.77**	0.99-2.93	0.79-2.16	0.64-1.66	0.80-1.58	0.77-1.40	0.85-1.40

7.9. Myelodysplastic syndrome (MDS)

MDS was considered a reportable cancer by many cancer registries from 2001 but the reporting is not considered reliable in Australia until 2003 allowing only 13 years of follow-up time in this report. There were 41 cases recorded in this time frame producing an elevated risk in the cohort population (SIR 1.21, 95% C.I 0.87-1.65).

The acknowledgement of MDS as a distinct disease has evolved gradually over the past century, characterised using vague and imprecise terminology to describe cases of MDS. Terms like “pre-leukemia,” “subacute leukemia,” and “atypical leukemia” were frequently employed to refer to these conditions.(105)

Approximately 20% of MDS patients will progress to AML but the two diagnoses are distinct diseases.(105) MDS was first defined in 1976 (106) and the diagnosis formalised in 1982.(107) In 2001, the World Health Organization (WHO) included it in their LH cancer classification scheme.(108)

There is also sparse literature on specific myeloid tumours, such as myeloproliferative disorders (MPD) and myelodysplastic syndrome (MDS), which can precede and evolve into AML. MDS covers a group of hematopoietic malignancies that have become recognised relatively recently and so has been under-reported in the past. IARC (94) did not mention these myeloid tumours in their recent evaluation of benzene carcinogenicity. The CONCAWE-funded combined study, however, found an association between benzene exposure and MDS at low exposure levels.(22)

7.10. Smoking

Smoking related diseases, lung cancer, cancer of the lip, oral cavity and pharynx, ischaemic heart disease mortality and chronic obstructive pulmonary disease mortality, were lower in the cohort than in the general population (see Section 5.1, Page 60).

However, within the cohort, smoking has a powerful influence on cancer and mortality. Altogether, it is estimated that smoking has been a contributing factor to the death of 1472 men, or 43% of the 3,419 deaths in the 'ever-smoker' group in the *Health Watch* cohort. This includes increases in heart disease, lung cancer, bladder cancer and chronic obstructive pulmonary disease mortality.

The death rate from all causes increased significantly with increasing tobacco use. Compared to non-smokers, those who smoke 30 or more cigarettes a day showed:

- a 4-fold increase in the death rate
- a nearly 5-fold increase in death rate from heart disease
- a nearly 40-fold increase in incidence of lung cancer

Risk of lung cancer and heart disease was clearly reduced by quitting smoking. Compared to non-smokers, those who quit showed:

- only a slight increase in mortality
- the death rate from heart disease was not significantly raised
- the risk of lung cancer remained raised by more than six times compared to never smokers, but the risk dropped by almost 90% compared to the highest smoking group.

8. CONCLUSIONS

Generally, the chances of dying, or of getting cancer or heart disease were very similar no matter where *Health Watch* people worked and compared favourably with the rates in Australian men. The age-adjusted death rate in men and women was significantly lower than the general Australian population. The strong *healthy worker effect* for mortality identified in previous studies continued to be observed.

All major cancer categories for women were similar to the expected rates. Mortality due to circulatory, IHD, cerebrovascular disease and external causes such as accidence and suicide were all lower compared to the Australian population The numbers of women recruited into the *Health Watch* program was very small which precluded detailed analysis.

For men, death rates in all major disease categories were lower than for the corresponding Australian population. All major disease categories except deaths from nervous system diseases were reduced. A significant reduction in all-cause mortality was seen among men in each workplace type e.g. refinery, terminal or upstream.

Smoking related diseases were lower in *Health Watch* members, than in the general population. However, within the cohort, there was a clear dose-related pattern, so that increased rates of smoking was associated with increasing risk of all-cause mortality and cancer. Smoking-related diseases are becoming more evident as the cohort ages. Quitting cigarette smoking greatly reduced the risks.

The chance of contracting cancer was similar for men and women in this industry as for all Australians. However, mortality from cancer was reduced for *Health Watch* members, particularly among men.

There was no evidence of increasing mortality, cancer incidence or increasing cancer mortality with any of the following:

- increasing duration of employment
- increasing time since first employment

There was no significant trend of increasing cancer mortality by duration of employment when compared to those employed for less than 10 years. There was an increased risk of mortality in the group 10-15 years of employment which is likely to be due to the very low rate of cancer mortality in the comparison group. Upon further analysis, compared to those with less than 13 years of employment, this increased risk was no longer evident and the trend for a decreased risk in cancer mortality with duration of employment became evident.

Cancer of the lip, oral cavity and pharynx, liver, lung, and leukaemia were all significantly lower in the cohort compared to the Australian population. Three cancers, mesothelioma, melanoma, and prostate cancer continue to occur at higher rates than those expected. Mesothelioma, likely a result of asbestos exposure, is fortunately a rare cancer and while there remains an excess risk, few cases have been newly identified in the cohort.

Melanoma incidence but not melanoma mortality risk was raised for men. This may indicate a screening bias, in that more melanomas are identified in these workers and treated. The risk of melanoma remained elevated when the cohort rates were compared with relevant state rates rather than the national rate. The sustained elevation was not observed in a previous report. (23)

Prostate cancer occurred at elevated rates for the first time in the previous report and is shown again in this latest analysis. This may also be a result of increased screening in this population because prostate cancer mortality, was the same as that for the general population. Cancer of the bladder and leukaemia are no longer in excess. In fact, rates of leukaemia are now lower in the cohort compared with the Australian population.

Cancer mortality rates were similar across the main job groups; however, cancer incidence was significantly elevated among drivers. The only cancers that were occurring at a higher rate among drivers compared to the general population were melanoma and prostate cancer. Oesophageal cancer risk among drivers is also elevated (SIR 1.80, 95% C.I. 0.98-3.01). Oesophageal cancer is strongly linked to smoking and alcohol consumption (109, 110) There was an increased proportion of ever smokers among the driver group compared with the entire male cohort. There were 73% of drivers who were recorded as ever smokers (this includes ex-smokers), compared with 64% for the other main job groups. The increased smoking rate in drivers compared with the male cohort may account for the excess of oesophageal cancer in this group.

Incidence rates of leukaemia and bladder cancer continue to be statistically elevated in drivers compared with office-only workers and kidney cancer rates were elevated but not statistically significantly so. The number of cancers in these groups, however, were comparatively low and therefore were associated with wide confidence intervals.

The cohort is aging and patterns of diseases are stable and have changed little compared to the previous report.(28)

9. THE RE-OPEN *HEALTH WATCH* COHORT

9.1. Introduction

A *Health Watch* Survey was offered to all current petroleum industry employees of Exxon-Mobil, BP, Shell, Caltex, Woodside and Chevron in 2010 to create a new study cohort. This means that members of the original *Health Watch* study who were still employed, as well as new employees, were offered the opportunity to become part of a new study cohort. The decision to offer a survey to new employees was based on the declining proportion of current employees who were members of the existing cohort, in large part through natural attrition linked to an ageing cohort, and recognition by Monash University, AIP and participating petroleum companies, of the importance of maintaining a longitudinal health study of petroleum industry employees in Australia.

Monash developed a list of generic job classifications or titles, which meets the current job descriptions, as a more suitable replacement for the previous hydrocarbon ranking scheme. This classification is used in the re-opened *Health Watch* cohort.(28)

9.1.1. Eligibility

The sixth *Health Watch* Survey was a whole of site survey: i.e., all employees of participating companies located at an eligible worksite at the time of survey were invited to take part. This included existing members of *Health Watch* and staff with primarily administrative or management responsibilities. Eligibility was limited to worksites which deals directly with the production, refinery, or distribution of petroleum products: for example, terminals, refineries, and airport fuel depots. Eligibility criteria is detailed in the 15th *Health Watch* report.(28)

Although contractors engaged in activities at eligible worksites were not invited to participate in this survey, some may have completed the questionnaire but were advised that their contact with *Health Watch* will be limited where they are not existing members or participating company employees. Their data will be held but was not included in the study analysis.

9.1.2. Survey Implementation

The format of the 6th *Health Watch* Survey closely resembled previous surveys utilising an electronic questionnaire as the main survey tool, which could be accessed ether offline or online. For individuals who were unable or unwilling to fill out the survey electronically, a paper questionnaire was provided. Additionally, participants had the option to complete the survey remotely through telephone arrangements.

9.1.3. Informed consent

Prospective participants received an Explanatory Statement that presented essential details about the study's objective, participant engagement, confidentiality and the handling and utilisation of data in easily understandable language. The statement also included contact information for the project and for the University's research complaints procedures via MUHREC. Obtaining informed consent was a requirement for participating in the study and

was acquired during the recruitment process when individual employees completed a Participant Consent Form.

9.2. Recruitment

9.2.1. Company Site Visits

Only onshore facilities in Victoria received a site visit by *Health Watch* researchers. Employees at offshore facilities received an invitation to complete the survey online; some may have been captured in transit at airports or heliports by arrangement or incidentally at other locations. Generally, only sites with more than 30 employees were assigned a dedicated scheduled site visit; however, some smaller sites were scheduled in conjunction with a visit to a larger site in reasonable proximity.

9.2.2. Remote On-line Recruitment

The interface for the remote online database mirrored the laptop database. The front end could be accessed via a dedicated website on the Monash University *Health Watch* page

9.2.3. Email/Postal Invitation to Employees

All eligible employees who had a work email address and who did not have the opportunity to complete the survey during a site visit were sent an email invitation to participate in the *Health Watch* study. In cases where an employee did not possess a work email, they received an identical invitation sent via post to their workplace address. The email invitations were sent to the employees' email address and included a link to a direct entry point for their individual survey. The employee was then prompted to enter their Employee Number to gain access to the explanatory statement, consent form and the survey. Employees who received a postal invitation were prompted to go to the *Health Watch* website and enter their unique *Health Watch* ID which was provided in the letter.

9.2.4. Office-only Employees

Office-only employees who were existing *Health Watch* participants were identified by participating companies. These members were also added to the new database and invited to participate in the sixth *Health Watch* survey. Office only employees not part of the existing cohort were not invited to participate in the Re-open Cohort.

9.3. Non-Responders

After the completion of the on-site or on-line survey, a list of non-responders was sent to corresponding companies to identify those employees who resigned/retired prior to receiving a *Health Watch* invitation. Returned postal and email invitations were also recorded. Email returns were either a non-deliverable email, or an automated 'out of office' response. These returns were important to calculate participation rates.

9.4. Participation

The sixth *Health Watch* survey was received positively from about half of the employees from Company worksites. Almost 45 % of employees at Worksites either completed a survey or consented to the study but did not complete the entire survey. Of the 5110 employees from pre-registered worksites, only 19 employees actively refused consent to participate in the study survey, i.e., they logged into the survey site and checked the 'no consent' option. It should be noted that non-participation is not indicative of non-consent. There were over 1,000 employees pre-registered into the database who may not have received one or more invitations to the study for various reasons including resigned/retired, moved to different site, postal return to sender, etc. Most of these employees were those who left their employment prior to one or more of their survey invitations.

Table 59 shows a breakdown of participation for new and existing *Health Watch* members. Of the 5,239 eligible employees, 38% of these were existing *Health Watch* participants. It is interesting to note that 54% of existing *Health Watch* employees either started or completed the survey compared to 39% of eligible new employees. This either illustrated the familiarity and loyalty to the *Health Watch* brand by existing members and/or the ever-increasing resistance to surveys in general.

Table 59: Breakdown of existing *Health Watch* members and new participants (including Head and Home Office Employees who were pre-registered into the database)

	Elig. No. in DB	*Existing HW Count (%)	New Emp Count (%)	No. Completed survey TOTAL (%)	Existing HW complete survey (%)	New Emps complete survey (%)	Total no. Consents (%)	Existing HW consent (%)	New Emps consent (%)
TOTAL	5,239	1,985 (38)	3,254 (62)	2,188 (42)	1,002 (50)	1,186 (36)	2,347 (45)	1,080 (54)	1,267 (39)

* These figures were calculated by searching the existing *Health Watch* cohort database on Surname and Employee ID or Surname, DOB and the first three letters of first name. There may have been some existing *Health Watch* members that were missed and therefore underestimating these figures.

Workplaces that were visited experienced a significantly higher overall participation rate. Among employees at visited sites, 56% either completed the survey or provided consent, whereas the rate was only 20% at non-visited sites. Although office sites were not visited, they still had a relatively high participation rate of 49%, primarily because most of these employees were already members of *Health Watch*. It is worth noting that office employees might generally possess better computer literacy compared to worksite employees which could increase their likelihood of completing an online survey. Furthermore, for those who received email or postal invitations and completed their survey, the participation rate was higher following the initial invitation.

9.5. Results for the Re-Open Cohort

In this report, the re-opened cohort was matched to the NDI and ACD and analysed as a distinct group. The recruitment of the re-opened cohort occurred several years after the original *Health Watch* cohort had concluded, creating a gap that prevented the newer recruits from simply being appended to the existing cohort.

The number of cancer and deaths recorded in the re-opened cohort were too small to complete any meaningful analyses. A summary of the death and cancer counts is detailed in Table 60. Of the 24 deaths in men, 8 were due to malignancies and 7 due to ischaemic

heart disease. All deaths in women were due to cancer. There were no additional deaths in this analysis from the last analysis.(28)

Of the 150 cancers identified in men, 64 were in reproductive organs, particularly the prostate. Twenty-five cancers were identified as melanoma and 16 cancers were lymphoid, haematopoietic and related tissue cancers.

Of the 12 cancers identified in women, the majority were in the female reproductive organs, particularly breast, followed by cancers of the lymphoid, haematopoietic and related tissues.

Table 60: Summary of total cancer and deaths in the Re-open cohort

		Re-Open Total	Both Cohorts	Re-open Only
Men	Total	2,087	1,041	1,046
	Deaths	24	16	8
	Cancer Total	150	114	36
	Cancer Diagnosed Post Recruitment	78	61	17
Women	Total	328	78	250
	Death	<6	0	<6
	Cancer	12	<6	9
	Cancer Diagnosed Post Recruitment	7	<6	6

9.6. Summary

The sixth *Health Watch* survey was conducted as a comprehensive assessment, open to all employees at eligible worksites of participating companies. The survey maintained a similar structure to previous surveys, employing an electronic questionnaire as the primary survey tool. Participants had the option to complete the survey during an on-site visit or independently online following an email or postal invitation.

In general, the survey was received positively by most employees. Existing *Health Watch* members exhibited a higher participation rate compared to new employees (54% versus 39%). Additionally, worksites that were visited by a Monash researcher demonstrated significantly higher participation rate compared to sites that were not visited (56% versus 20%). It was anticipated that participation would be more significant at visited sites where a Monash presence was established, however, due to financial constraints, it was not feasible to visit numerous remote and smaller sites. Moreover, it is worth noting that individuals with a prior cancer diagnosis may have displayed a greater inclination to participate, potentially introducing bias to this particular cohort due to the low recruitment rate.

10. ACRONYMS

ABS	Australian Bureau of Statistics
ACD	Australian Cancer Database
ACTU	Australian Capital Territory Union
AEC	Australian Electoral Commission
AIHW	Australian Institute of Health and Welfare
AIP	Australian Institute of Petroleum
API	American Petroleum Institute
BDM	Births, Deaths, Marriages
CI	Confidence Interval
CONCAWE	Conservation of Clean Air and Water in Europe
COPD	Chronic Obstructive Pulmonary Disease
DIMIA	Department of Immigration and Multicultural and Indigenous Affairs
DOB	Date of Birth
HW	*Health Watch*
HWAC	*Health Watch* Advisory Committee
ICD	International Classification of Diseases
IHD	Ischaemic Heart Disease
IOL	Imperial Oil Limited
LH	Lympho-haematopoietic
MDS	Myelodysplastic Syndrome
MonCOEH	Monash Centre for Occupational and Environmental Health
MPD	Myeloproliferative Disorder
MUHREC	Monash University Human Research Ethics Committee
NDI	Nation Death Index
RIR	Relative Incidence Ratio
RMR	Relative Mortality Ratio
SIR	Standardised Incidence Ratio
SMR	Standardised Mortality Ratio
SPHPM	School of Public Health and Preventive Medicine
VCR	Victorian Cancer Registry

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