ADELAIDE UNIVERSITY
AUSTRALIA

HEALTH WATCH
The Australian Petroleum Industry Health Surveillance Program

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The Australian Institute of Petroleum Health Surveillance Program

Eleventh Report
2000

The University of Adelaide
Department Public Health

This Eleventh Report updates the previous report published in 1999. It contains an analysis of deaths occurring up to the end of 1998, and cancers registered up to the end of 1996.

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In 1979 the Australian petroleum industry took the initiative to set up this health surveillance program to report on the long-term health of its employees. The Australian Institute of Petroleum contracted with the Department of General Practice and Public Health at The University of Melbourne to run Health Watch and the program, still the only one of its kind in Australia. Health Watch consists of a cohort study, in which the long-term health of oil industry employees is followed over time, and a case-control study, which focuses on the relationship of certain blood and bone-marrow cancers to benzene exposure. In 1999 the contract for the cohort study was taken over by the Department of Public Health at Adelaide University. Responsibility for the case-control study passed to Monash and Deakin Universities. This report updates the findings of the cohort study.

Health Watch continues to provide valuable information to the participating companies, assisting them in the development of policies and programs that are providing safe and healthy working environments for employees in the industry.

The Australian Institute of Petroleum welcomes the Eleventh Report.

Brian Nye
Executive Director Australian Institute of Petroleum

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MEMBER COMPANIES WHOSE EMPLOYEES ARE COVERED BY HEALTH WATCH

Caltex Oil Australia (incorporating Total, Ampol Australia and Australian Petroleum Pty Ltd

BP Australia Limited (incorporating Amoco)

ExxonMobil Australia Ltd (formerly Esso Australia Ltd

and Mobil Oil Australia Limited)

Santos Ltd

The Shell Company of Australia Limited

Chevron Australia (formerly West Australian Petroleum Pty Limited (WAPET))

Woodside Offshore Petroleum Pty Ltd

Airport Fuel Services

Castrol Australia Pty Ltd (up to 30/6/94)

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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 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 State death and cancer registries for confirmation of information.

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

CONTENTS

OVERVIEW OF HEALTH WATCH

Health Watch is an epidemiological health surveillance program that was run by The University of Melbourne on behalf of the Australian Institute of Petroleum from 1980-1998.

Health Watch covers those petroleum industry employees from all major oil and gas companies who voluntarily joined the program at their work sites across Australia. About 95% of the industry's employees approached to participate, from refineries, gas plants, distribution terminals, and production sites, onshore and offshore, have joined Health Watch.

Health Watch consists of a prospective cohort study of all-cause mortality and cancer incidence and a case-control study of leukaemia and benzene exposure. In 1999 Adelaide University took over responsibility for the cohort study. Responsibility for the case-control study has been passed to a Victorian consortium from the Monash and Deakin Universities, and its findings are the subject of a separate report.

Employees in the industry have been surveyed about every five years using a detailed job and health questionnaire administered by University research interviewers. This process obtains information on job tasks, on lifestyle factors including smoking and alcohol, and on health status.

An employee is taken into the cohort analysis after having served five years in the industry and remains in the Health Watch cohort for life.

Employees who leave employment with participating companies are contacted periodically to obtain an update of their employment and their health status.

The employing companies maintain the flow of information on entrants, job changes and retirements. Contact with cohort members is maintained until death. Death registrations and cancer registrations are obtained from the Australian Institute of Health and Welfare, which now compiles the National Death Index and the National Cancer Statistics Clearing House on behalf of all State Death and Cancer Registries.

The results from the Health Watch program have been published in reports from the University program director and in several papers in scientific medical journals. Results are published on the University world-wide-web site on the Internet. Summary reports are regularly distributed to all employees and former employees in the Health Watch cohort.

SUMMARY OF FINDINGS

This report is based on analysis of the Health Watch cohort, with mortality data updated from the National Death Index to the end of 1998 and cancer incidence updated from the National Cancer Statistics Clearing House to the end of 1996. Both of these national data sets are maintained by the Australian Institute of Health and Welfare on behalf of State death and cancer registries.

The age-standardised death rate for men and women is significantly less (69% and 60% respectively) than the population death rates.

18 female cohort members have died, 14 from cancer. This high proportion of deaths from cancer is in fact due to very low death rates from other causes. The standardised death rate from cancer in females is no different from that of the Australian female population in general. 47 cancers have occurred, representing a small excess, which is mainly accounted for by an excess of melanoma. This may be caused by a high reporting rate rather than a true increase in incidence rate. This is particularly likely to be so in the case of female workers, since in this industry few if any women are subject to any of the occupational exposures likely to cause or accelerate the onset of this condition.

865 males have died. The standardised death rates for all major causes of death (including cancer) are significantly less than the population death rates.

The chance of getting cancer is the same for men in this industry as for other Australians. Those who worked in the industry in earlier times may have been at greater risk for cancer than those who entered the industry more recently. Cancer incidence also shows a tendency to increase with increasing duration of employment in the industry. However the significance of these findings is unclear since the overall cancer incidence in the Health Watch population is the same as that of the general male population.

Smoking has a powerful influence on mortality. The death rate from all causes increases significantly with increasing tobacco use. People who smoke 30 or more cigarettes per day have more than a 3-fold increase in standardised death rate than lifelong non-smokers. Similar trends were found for mortality from heart disease and cancer. Cancer incidence showed a smaller but significant increase with increasing tobacco use. Lung cancer mortality and lung cancer incidence have an extremely strong relationship with smoking. People who smoke 30 or more cigarettes per day have approximately a 100-fold increase in lung cancer incidence and mortality compared with lifelong non-smokers. There is a clear reduction in risk of lung cancer and heart disease from quitting smoking.

The overall mortality rate in people with low to moderate alcohol consumption appears to be reduced in comparison with non-drinkers. Beyond 5 drinks per day, the mortality rate rises to a higher level than in non-drinkers.

11 mesotheliomas have occurred in the cohort, mainly in refinery maintenance workers and operators. It is likely that several of these cancers are related to asbestos exposure in refineries, mostly before the 1970s, although some are likely to have resulted from asbestos exposure occurring prior to entering the oil industry. Asbestos exposures do not appear to have been sufficient to cause any appreciable effect on the incidence of lung cancer.

There is an increased incidence of melanoma, which is likely to have resulted from increased rates of reporting rather than from any causal exposure in the oil industry. The mortality rate from melanoma is not significantly different from that of the Australian male population.

There is a significantly increased incidence of bladder cancer, and the possibility of an occupational cause cannot be excluded.

There is an excess incidence of multiple myeloma. However the number of cases is too few to assess the possible relationship to workplace exposures.

There is a statistically significant increase in incidence of all leukaemias combined. Time-related analyses do not suggest a causal association with employment in the industry, but there is an increasing risk with increasing exposure to total hydrocarbons, using hydrocarbon rank score as an index of exposure.

1. INTRODUCTION

1.1. Industry Background

The petroleum industry became established in Australia in the first decade of the twentieth century when international companies began importing fuels and lubricants. Refineries were built from 1910 onwards and nationwide distribution networks were set up, with the distances involved leading to considerable cooperation between the competing companies which were servicing a relatively small, scattered population. World War II was followed by a period of rapid population expansion. Refinery and associated petrochemicals plant development took place with major refineries in three States coming on-stream during the 1950s. Technological development has continued to date in line with the world-wide oil and gas industry. Australian refineries and terminals are technologically advanced although relatively small in capacity. Environmental legislation and emission controls are amongst the most stringent in the world, and this has resulted in changes in technology, eg introduction of bottom loading of road and rail tankers and hydrocarbon vapour recovery systems.

Local production of both oil and gas has grown, and from the 1970s the production of light crude oil and of natural gas has made Australia a net energy exporter. Development of new and existing fields continues around the continent and overall production continues to grow. In the last ten years the industry has undergone considerable re-organisation leading to fewer people being employed by the petroleum companies, with a significant proportion of work now undertaken by contractors. The petroleum industry is represented by the Australian Institute of Petroleum (AIP) which was founded in 1975 and established a Health Committee in the same year.

1.2. Development and Design of the Health Watch Surveillance Program

In 1980 the Australian Institute of Petroleum contracted the Department of Community Medicine (now Department of General Practice and Public Health) at The University of Melbourne to establish an epidemiological health surveillance program to monitor major health outcomes of employees in the industry. The program, called *Health Watch*, has been running continuously since that time, monitoring major health outcomes in the **cohort**[†] of people who work in the industry. As Australia's oil and gas development has expanded, new companies and projects have entered the program.

Since 1987 the cohort has shown an overall excess of lymphohaematopoietic cancers (all leukaemias, multiple myeloma and all lymphomas except Hodgkin’s disease). To evaluate the relationship between workplace exposures (specifically benzene) and the excess of these cancers, a nested case-control study was commenced within the cohort in 1988.

In 1999 the University of Melbourne relinquished responsibility for *Health Watch*, and the AIP contracted Adelaide University to continue the cohort study. Responsibility for the case-control study was passed to a consortium at Monash University and Deakin University. By arrangement, with approval of the Adelaide University Ethics Committee, information for conduct of the case-control study was provided to the consortium.

Although all the major petroleum companies have joined the *Health Watch* program of the AIP, participation by individual employees is voluntary. The health outcomes monitored are deaths from any cause (all-cause mortality) and the incidence of cancer. These measures provide a broad view of the health experience of people working in the participating companies over the past five decades. Cancer Registry data available since about 1970 has allowed cancer incidence to be recorded and analysed.

The overall design of the *Health Watch* program is that of a prospective cohort study. The cohort information is routinely analysed for occupational exposure effects and the design allows for other

[†] A **cohort** was originally a group of Roman soldiers who marched together. The *Health Watch* cohort is made up of people working in the industry who are marching together through time.

research studies as and when required. *Health Watch* has also responded to some queries regarding particular job categories or sites producing data for specific reports. No clinical examination or physical monitoring procedures are used in the program.

Figure 1 is a representation of the *Health Watch* cohort structure.

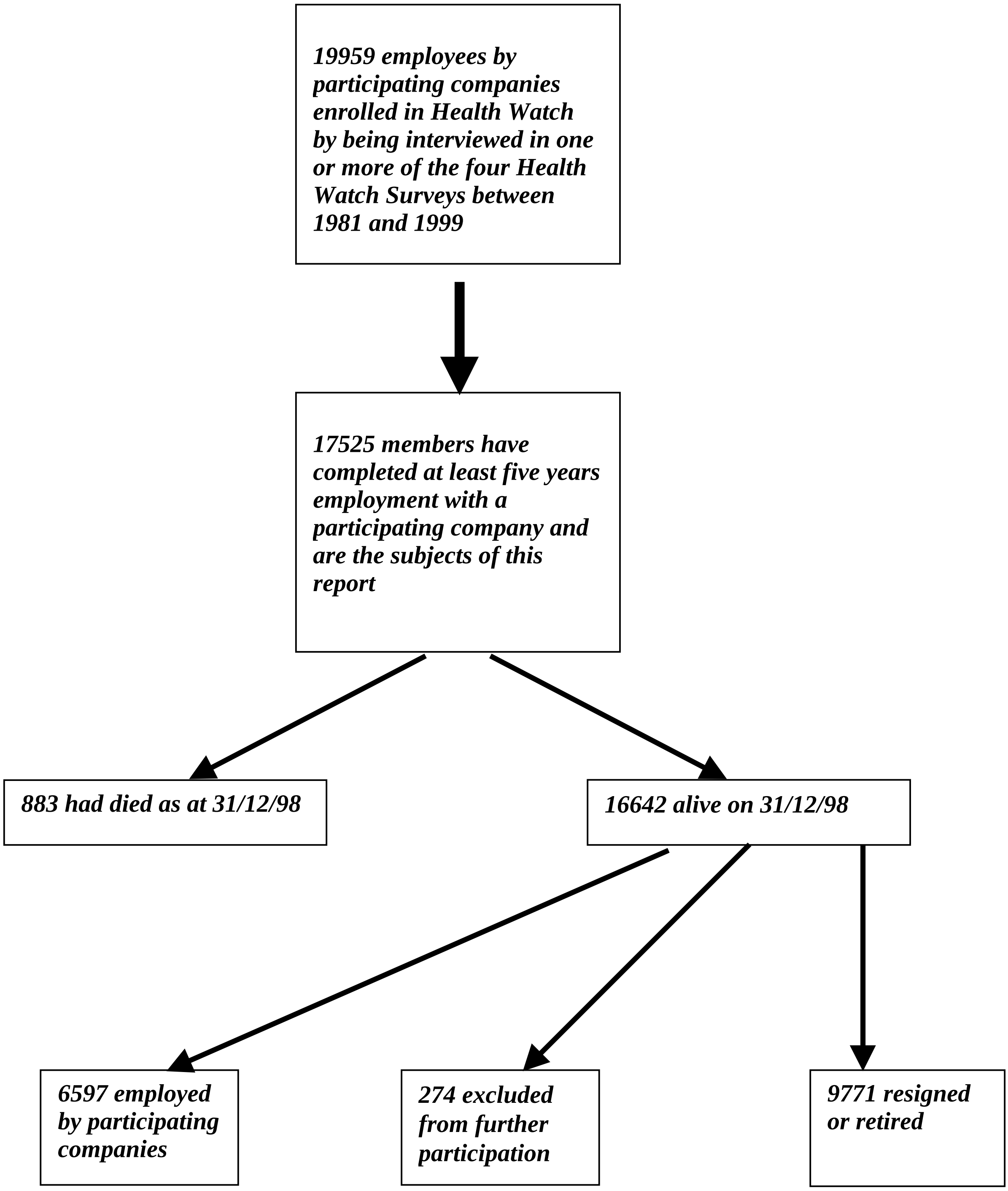

Figure 1: *Health Watch cohort structure*

1.3 Reporting Results

Results are reported to the Health Watch Advisory Committee comprising:

- representatives of the Executive Director of AIP
- representatives of member companies of the petroleum industry
- persons appointed by the ACTU representing trade unions in the industry
- representatives from Adelaide University.

Results are published in this report, and in leaflets which are provided to all *Health Watch* sites for distribution to employees, and sent by post to all individuals who have resigned or retired.

- Publications for medical and scientific journals are prepared on parts or the whole of this research program.
- The leaflets are prepared by the *Health Watch* project team and set out the purpose, methods and results in straightforward language.

1.4. Consent and Confidentiality

1.4.1 Ethics committee approval

The *Health Watch* program deals with matters relating to medical and human research ethics, informed consent, and confidentiality. The work of the *Health Watch* cohort study has been approved by the Ethics Committee of Adelaide University.

Issues of principle are dealt with by the Director and the Department of Public Health at the University in consultation with the Advisory Committee.

1.4.2 Confidentiality

All information is kept at Adelaide University and results are published in such a way that no individual member of the cohort is identifiable. The University's Guidelines on Confidentiality of Research are followed and only members of the *Health Watch* team have access to the data. Under the terms of the contract between the AIP and the University, all members of the team are bound by formal confidentiality agreements.

All *Health Watch* approaches to cohort members are assessed and approved by the Advisory Committee. Project team members are aware of the need to avoid distress in their dealings with individuals or their families. Medically confidential matters relating to individual members of the cohort are handled within the project by the Director who is a medical practitioner.

Health Watch obtains information from subjects, their next-of-kin, families, relatives, employers, and the Australian Institute of Health and Welfare, which maintains the National Death Index and the National Cancer Statistics Clearing House on behalf of State registries. Signed consent is obtained from every subject in the cohort to obtain relevant information, and specifically to search Cancer Registries and to approach employers for job histories. These consents are kept permanently and continuity of consent is obtained at each re-survey. Information regarding the consent and its implications is provided to potential entrants at briefing sessions on site, in writing, and at the time of interview.

1.5 Present Work

This report covers the period of results and their analysis up to November, 2000. The Fourth National Health Watch Survey began in September 1996 and was completed in 2000. The survey has updated the cohort and extended it to cover the new entrants into the industry since 1993. Funding has been provided by the Australian Institute of Petroleum up to December 31, 2000.

Summary box

Health Watch is monitoring the health of people who have worked in the Australian petroleum industry since 1981. As time has gone by, Health Watch has been able to look more closely at particular job groups and the different parts of the industry. This has only been possible because the people in the Health Watch cohort have supported the program during the past twenty years.

Health Watch is providing information which people in the industry need to make good decisions about health and safety.

2. EPIDEMIOLOGICAL PROCEDURES

2.1. The Health Watch Study Population - the Cohort

The cohort was initially established by the first survey in 1981-83. Surveys have been repeated in 1986-87, 1991-93 and 1996-2000.

A major difficulty in the design stage of prospective studies is to know what information will be needed on each subject for future analysis. The volume of data collected is inevitably limited because of time and cost. There is also a need to avoid overloading of the voluntary participants.

All employees of petroleum companies operating in Australia working in refineries, storage and distribution terminals, offshore and onshore production facilities and airports were, and have continued to be, eligible to become members of the *Health Watch* cohort. For reasons of cost, employees working in capital city offices and sites with fewer than 10 employees are excluded.

During the periodic surveys, entry to the *Health Watch* cohort register is gained through voluntary attendance on site, for personal interview with a University project team interviewer. 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 notebook portable computers. Interviewers were trained in the application of the questionnaire. The interviewer had access to all the previous job history of current members and could accept potential corrections to previous data. In May 1999 the AIP contracted with Adelaide University to complete the fourth survey by mail and by telephone.

The repeated surveys have allowed updating of information for each member of the cohort population still employed, and the recruitment onto the cohort register of all new employees in the industry. Information updated by re-survey includes job history, exposures and confounding factors.

Full and informed consent procedures are undertaken for each employee during pre-interview briefings to all employees in groups and individually at the time of interview. The major purpose of the briefings during surveys is to explain the nature of the program, the implications of entry and the consent procedures, and to provide feedback to existing and prospective cohort participants.

Once entered in the cohort population, six-monthly updates are provided on employees by the companies, so that notification is given on transfers between sites and resignation, retirement or redundancy.

Tracking of the members of the *Health Watch* cohort is through company records and the national surveys for those still employed and by regular mail contact for those who have left the industry.

However, the names of those lost to direct contact are searched at intervals against all State Death and Cancer Registries, thus reducing the impact of losing direct contact.

The mail contact consists of a letter sent at about 2 yearly intervals to all those members who have resigned, retired or been made redundant. The letter requests information about any serious illnesses, including cancers, suffered since the previous contact.

In 1994-5, for the first time, additional information was requested. This related to the retrospective exposure assessment project within *Health Watch,* and asked for additional detail about all jobs ever held in the petroleum industry and smoking habit since the member's most recent survey interview.

The most recent letter was sent to former employees in 1999. Of 8024 letters sent, replies were received from 4423. A contributing factor to this relatively low response rate may have been that some cohort members have changed their address without notifying *Health Watch*. After consultation with the Adelaide University Ethics Committee a decision was made to try to update addresses through the addresses on the Australian Electoral roll. The Electoral Commission has agreed to supply *Health Watch* with information which is already available on the public record. With the assistance of the Australian Electoral Commission a search has been made for the addresses of former employees who did not respond to the 1999 letter and for other employees for whom no current address was available. All except 1464 have been located, and *Health Watch* is continuing its efforts to locate these remaining former employees and to maintain contact with all cohort members.

2.2. Analysis - Comparisons for the Cohort

From the register of participants, the cohort to be analysed is established by including all employees who have completed five years of employment in the industry. The cut-off point of 5 years service was selected for logistic reasons and for considerations of latency of cancer development.

Health Watch carries out external comparison of the cohort with the Australian national rates for deaths and cancer as published by the Australian Bureau of Statistics (ABS) and Australian Cancer Registries using appropriate standardisation to account for age effects.

Internal comparisons for different job and sector classifications and measures of exposure are also used for analyses, taking account of possible confounding variables, particularly smoking history, which is an important contributory factor to several diseases, and causes of death.

2.2.1. Measures of Exposure

Categorising of exposure to hazards is the key to cohort or case-control analyses which are designed to report on risk. It allows for stratification of the cohort population into exposure categories to allow internal comparisons; and into exposure groups for use in the case-control study. Although exposure categorisation is best done at the time of exposure, inevitably much of the information in *Health Watch* is a retrospective assessment of exposures which took place prior to 1980. Exposure assessment is the most difficult and intractable problem for the *Health Watch* program.

At the design stage of the program in 1978-79 it became apparent that very limited direct occupational hygiene measurement information was available. It was not possible, therefore, to stratify employees precisely by their exposure to hydrocarbons or other hazardous substances encountered in the working environment. Several surrogate measures of exposure have been adopted, and are being added to or refined as more information becomes available. They include job descriptors, workplace type, time-related variables, and ranking for exposure to hydrocarbons.

Regulatory requirements in several Australian States for the control of exposure to hazardous substances (WorkSafe) are leading to more formal assessments of exposure in work areas. These assessments are required for individual jobs and the AIP has allowed for future linkage to *Health Watch* by requiring the AIP Jobcode to be entered on to assessment reports in the industry-wide training program for these regulations.

2.2.2. Job Descriptors - the AIP Jobcode and Collection of Job History information

A precise **job description code** is used as the principal exposure index for the cohort analyses, based on collection of a job history from each participant.

The job classification developed for the American Petroleum Institute is used[1,2] and this has been modified on the advice of occupational hygienists in the industry where additional Australian job categories were required. This classification, referred to as the Dictionary of AIP Jobcodes, enables an employee in the cohort to be categorised by the processes on which they work and can act as a link to exposure information.

Each employee's job history is recorded at a survey interview for any of the 50 processes in the Job Dictionary. Categorisation for analysis is on the process where most working time is spent as recorded at the first interview, and this is identified as the "AIP Jobcode". Where a person works on more than six processes concurrently, they are coded as "multiprocess"; this code also applies where the employee is rotated routinely around a number of processes.

During the first two surveys, as decided at the outset of the program, details were collected by interview on the current job held by each participant. Up to six separate jobs could be defined, making up time components aggregating into a single total job. Although some history of jobs prior to entering the petroleum industry was collected, the jobs carried out in the petroleum industry prior to the current job were only sought for up to five years prior to the first interview.

In 1990, when the focus for *Health Watch* turned to the need for a lifetime exposure history particularly to benzene (case-control study), it became apparent that the lack of complete job history for many of the cases and controls was a major problem. Estimations of exposure done by occupational hygienists from the industry were based on the assumption that jobs held by those in the case-control study were identical to those identified as current job at first interview or job held five years prior to first interview. For men in the younger age groups this was unlikely to be an unrealistic assumption. However, many of the case-control study members were found to have very long gaps in their job histories and it was recognised that jobs, and therefore exposures, might have been very different from jobs held in the five years prior to first interview.

In 1991-3, during the third survey, all participants were asked at interview about all jobs held during their employment in the petroleum industry. The response rate in the third survey was maintained at a high level, with about 96% participation rate in those still employed, and new employees. 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 still be incomplete, the computerisation of the fourth survey has allowed gaps in the information to be more easily identified and corrections to be made at the time of re-interview.

By the time of the third survey, about 4000 men and 250 women had left the industry after having had at least 5 years experience in it. Their complete job histories had to be collected by including questions relating to this in the annual health letter sent to all retirees. This was done in 1994-5. Retirees were generally longer serving employees than those still employed, and therefore had longer gaps in the job histories previously collected. For many reasons, their complete job histories are likely to be less certain than those still employed and interviewed in the third survey. 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.

The fourth survey commenced in 1996 and was completed in 2000. 1486 employees were interviewed for the first time in the fourth survey, and a complete job history was obtained from them. Job information was updated on other current employees. Cohort members who left the industry were surveyed by mail in 1999, and information requested on employment details since leaving the industry.

For the few cohort members who have not provided a complete job history, the previous assumptions about jobs have been maintained.

2.2.3. Workplace Type

Categorisation by workplace has been used as the main basis for internal risk comparisons. Five types of workplace were reported previously and these have been retained in this Report, namely: Refinery, Terminal, Airport, Onshore production and Offshore production.

2.2.4. Time-related Variables

Because the technology and work procedures, and therefore exposure, has been constantly changing in the industry over the past decades, health outcomes must be explored to ascertain whether they are related to historical exposures or reflect current risks.

Three parameters of occupational exposure which might throw light on any time relationships have been included in the analyses. These are:

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

("Employment in the industry" means employment with one of the participating companies.)

Period of first employment analyses may provide clues as to whether exposures in particular calendar periods may have had risks attached to them which perhaps are now no longer operating.

The analyses for **duration of employment** in the industry address the concept of cumulative exposure. Cumulative exposure over the whole period where exposure could have occurred is of interest, since for most chemical exposures, the exposure standards or limits are based on the concept that it is the cumulative effect of exposure which expresses itself in diseases such as cancer.

Consideration of elapsed **time from first employment** to diagnosis of cancer or death, is an attempt to explore what latency periods might be involved with the development of disease, particularly cancer.

2.2.5. Hydrocarbon Exposure Grouping

Exposure to hydrocarbons is one obvious measure of exposure to be considered for this industry. Petroleum industry occupational hygienists have considered exposure to hydrocarbons to be low, relative to Occupational Exposure Standards prevailing at various epochs, in all jobs and workplaces. Direct measurements of exposure for particular jobs, eg, in "parts per million in air, time weighted average" are generally unavailable for the several decades of interest to *Health Watch*.

To obtain some exposure classification, the processes or operating units used in the AIP Jobcodes have been classified by a committee of petroleum industry occupational hygienists into seven categories representing increasing potential for exposure to total hydrocarbons. This ranking represents the exposure situation in the early 1980s.

During 1994-6 the previously used total hydrocarbon rankings were reviewed and amended in the light of additional job history information. The total hydrocarbon categorisation is still regarded as a crude measure of exposure, but is the best available at this stage. Distribution of *Health Watch* person-years across these categories is unequal, with most jobs being in category 4. This has presented some difficulties in statistical analysis.

Analysis for total hydrocarbons has been additionally adjusted for smoking by dividing the cohort into smoker or never-smoker, and this provides a simple measure for use where numbers are otherwise small for analysis.

2.2.6. Job Type

Analysis of health outcomes for specific categories of job (single AIP Jobcode) is dependent on there being sufficient members of the cohort who carry out this particular job. Using the data available up to 1998 allows for analysis of the jobs with the largest numbers of employees in the industry, these being "Driver, Refinery Operator, Terminal Operative and Maintenance (terminal or refinery)". The latter two categories are composite groups brought together to allow for job type analysis. *Health Watch* data is not yet large enough for reliable analysis on other AIP job codes.

2.2.7. Confounding Variables

Confounding variables are other factors (aside from occupational exposure) which may be operating in members of the cohort population in ways which affect the health outcomes being studied. Where these factors can have large influences on outcomes, such as with smoking and cancer, it is necessary to account very precisely for these factors. Even small differences in exposure to tobacco smoke can cause large differences in lung cancer rates. Confounding variables may be unequally distributed amongst the different occupational exposure groups. Differences in risk between various exposure groups could therefore be masked or falsely calculated if confounding variables are not allowed for.

In the study design for *Health Watch* a number of potential confounding variables are taken into account including age, sex, smoking habit, and alcohol consumption. Socio-economic status may be a confounding variable but to date has not been taken into account in the routine analyses.

The occupational exposure variables which are of interest (workplace type, job category, exposure rankings and time relationships) are analysed with adjustment for confounding by age, calendar year and tobacco smoking. These confounding variables were chosen as they are known to have major effects in the Australian population. 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.

At each survey, standard questions on present and past smoking habit are asked of each participant. Because of its importance, the smoking risk analysis has been enhanced and updated in the Tenth and Eleventh Reports. Smoking status has been updated for the whole cohort, to reflect more accurately their lifetime smoking habit. National smoking data are derived from national survey data.[3]

Information on alcohol consumption is collected during the survey interview. Each cohort member interviewed is 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 can then be estimated.

2.3. Health Outcomes

2.3.1 Focus on Cancer

When the concept for *Health Watch* was developed in 1978-9 it was decided that the program should focus primarily on the question of whether working in the petroleum industry carried any excess risk of cancer.

The study design was modeled on that question, but was to be flexible enough to provide reliable information about all causes of death as well as cancer incidence.

2.3.2 Cancer incidence

A distinguishing feature of the *Health Watch* program, amongst cohort studies in the petroleum industry around the world (or indeed any industry), is its ability to consider the occurrence or incidence of cancer which is not necessarily fatal. This is made possible by the existence of population-based Cancer Registries in all Australian States. Cancer is a notifiable disease in all States and Territories and all cancers, except non-melanotic skin cancer, and all deaths are legally notifiable in Australia.

National data on cancer **deaths** have been available for many years, based on information on medical certificates of cause of death, as provided to the Registrar of Births, Deaths and Marriages in each State and Territory. However, the major question for studies of the effects of occupational (or other) exposure is how many people **get** cancer, which is fortunately not the same as how many people **die** of cancer. In the majority of cancers, treatment prevents death from the cancer, or prolongs life considerably. In long-term studies like *Health Watch*, the improvements in treatment can change death rates even where incidence is unchanging. For this reason, where incidence can be determined, it is a far better research method for cancer causation than death rates.

Cancer Registries in each State and Territory receive notifications of all cases of cancer, and report on incidence of the various types of cancer, by age and sex. Notification is mandatory for treating physicians and verification is obtained from hospital, pathology, radiotherapy and physician records. Cancer registration has been universal in Australia and complete since 1982.

In June 1984 the National Health and Medical Research Council endorsed the concept of a national collection of cancer statistics and a National Cancer Statistics Clearing House (NCSCH) now compiles data produced by individual State and Territory Registries.

Health Watch links with Cancer Registries to produce incidence data for the cohort. At intervals, national cancer incidence data are assembled from pooled State figures, and these rates are used for comparison with *Health Watch* figures.

Cancer incidence rates may change in a population over long periods, due not only to “real” changes in incidence but also because of better diagnosis, or changes in definitions. These changes have to be considered when commenting on *Health Watch* figures.

2.3.3 Cancer deaths (mortality)

Cancer is a major cause of death in Australia, with deaths due to many of the most common cancers continuing to increase. The proportion of male deaths from cancer continues to rise steadily, with ABS data indicating that it has risen from 23% in 1981 to 29% in 1998. This is probably due to the ageing of the population and reduced death rates from other causes, eg ischaemic heart disease which has dropped during the same period from 30% to 22% of all male deaths. In order to provide interstate consistency in cancer death statistics, the Australian Bureau of Statistics information has been used in this report.

2.3.4. Cancer notification and identification within *Health Watch*

In the case of any death certificate where "cancer" appears as the underlying cause, or where notification of an incident case is received from survey interview or annual health return, the type of cancer is checked against data obtained from the periodic searches of the National Cancer Statistics Clearing House. The names of those *Health Watch* study members who have given consent are also matched at intervals against the Cancer Registry files.

Written permission to obtain medical details about any case of cancer has been obtained from all but a very few members of the cohort. With regard to cancer analyses, any person in the cohort may appear as:

- a **case** because the diagnosis was after 1981 when *Health Watch* began, and was within the periods for which the Cancer Registries can provide up-to-date figures;
- a **death**, because death has been notified between 1981 and the end of 1996; or

- both a case in the incidence data and a death in the mortality data.

2.3.5. Cancer Incidence Validation

Complete follow-up of people in *Health Watch*, to ensure that all cases of cancer are known is ensured by matching the names of cohort members at regular intervals against data in the State Cancer Registries. This information is now collected on a national basis from the National Cancer Statistics Clearing House, which is complied from the State Registries and maintained by the Australian Institute for Health and Welfare. (South Australian Cancer data are an exception, as these are obtained directly from the South Australian Cancer Registry.)

The 1999 search of the National Cancer Statistics Clearing House revealed a number of inconsistencies between identified cancers and cancers already in the *Health Watch* data base. Each of these was checked with the relevant State Cancer Registry. In most cases it was found that the cancer coding had been updated in the light of further histological or clinical information. This has led to recoding of some cancers.

Incidence is regarded as the first known occurrence of a primary cancer. To conform to the rules of the Cancer Registries, only cancers coded in the range 140-208 of the International Classification of Diseases Revision 9 (ICD9) manual are regarded as "cancers" for incidence purposes. Non-melanotic skin cancers (ICD9: 173) are not generally recorded by the Cancer Registries, so that for the analyses comparing skin cancer rates in the *Health Watch* cohort with national rates, only melanomas are included.

2.3.6. Death Notification

The Australian Bureau of Statistics (ABS) compiles national annual cause of death statistics (mortality rates). Consideration of all causes of death can provide a broad picture of major health patterns, as these are directly linked to death outcomes. Some medical conditions, where death is not a consequence, eg, *arthritis*, cannot be reported on by *Health Watch*. Others, where there is a link between number of deaths and overall morbidity (ill-health), such as *ischaemic heart disease* and *accidents*, can be reliably explored using *Health Watch* information.

Notification of deaths in currently employed members of the *Health Watch* population is supplied by the employer. Deaths of members who have left the industry may be notified by the previous employer, or by the family in response to the mail contact.

A search of the National Death Index (NDI) is undertaken at the same time as the national cancer search. The NDI is also maintained by the Australian Institute of Health and Welfare, and a list of all registered deaths of persons matching members of the *Health Watch* cohort is provided, with causes of death coded by the Australian Bureau of Statistics. This allows valid comparisons with national statistics. Where a cohort member is known to have died whilst overseas, the death certificate is obtained from either the next of kin or from the death registry of the country where the member died.

This coded deaths are used for all comparisons made with Australian statistics resulting in the calculation of a comparative index called the standardised mortality ratio (see section 2.4.1). It is this measure which is used for the purposes of risk analysis.

Searches of death registries are carried out every few years to confirm that all deaths have been identified. The 1999 search of the National Death Index revealed 188 deaths not previously known to *Health Watch.* However only deaths occurring up to 31 December 1998 are included in the current analyses.

2.4. Measures of Comparison

2.4.1. The SMR and SIR

Health Watch compares death and cancer rates in the petroleum industry with the national rates to produce measures called the **standardised mortality ratio (SMR)** and the **standardised incidence ratio (SIR).**

The SMR is a measure of the death rate occurring in the *Health Watch* cohort population compared to the death rate occurring in the national population. This ratio can be measured for the whole cohort population or any subset, for any particular cause of death, or for all causes. The SMR tabulations show the number of deaths which are "observed" in the *Health Watch* population and the calculated "expected" number which would arise in a group of the same age and sex in the Australian national population.

When epidemiological analysis is carried out on death rates, comparison is made between the group of workers and the national or other reference population from which they come. The **observed** number of deaths (O) in the working group, over a time period, is compared to the number of deaths which would be **expected** in a group of that size (E), and age structure, if the reference population death rates applied to that group. The outcome of that calculation is the SMR (**S**tandardised -for age- **M**ortality **R**atio). When there is no difference between the group of workers and the reference population, the SMR is 1 (unity) or 100 (O=E and so O/E=1).

The number used as the ***expected*** deaths depends on which reference population is selected to be the comparison, and which time periods are used. The practice varies from country to country (UK studies nearly always use national rates, US studies sometimes use State rates, occasionally researchers use local rates). These comparison rates can vary quite substantially, and obviously affect the O/E ratio or SMR outcomes.

Therefore, in addition to considering the statistical outcomes, the context must also be considered, including factors such as the “healthy worker” effect (see below). Enlarging studies, re-examination of the data, re-validating diagnoses and other measures might all be appropriate where suspicion is aroused by initial results.

To calculate SMRs, *Health Watch* uses death statistics and population data from the Australian Bureau of Statistics (ABS) which routinely pools all data from the State Death Registries. The death rates occurring in the *Health Watch* cohort are standardised for age against the ABS statistics. The standard rates used for deaths which occurred up to the end of 1985 are the average national rates across 1981-5, those used for deaths in 1986-1990 are the average rates for 1986-90. Deaths in 1991-1995 are the average rates for 1991-95, and those used for deaths in 1996-1998 are the average rates for 1996-98. National rates do change, although slowly, and comparisons therefore need to take this into account.

Comparison of the "observed" number of deaths recorded by *Health Watch*, to the "expected" number, as shown in the tables, 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 death in the *Health Watch* cohort compared to Australians as a whole, with age and sex taken into account. When this applies to all causes of death, the SMR can be regarded as a crude indicator of length of life.

For measuring the risk of developing cancer the standardised incidence ratio (SIR) is calculated. Incidence measures cancer as it arises as opposed to when it causes death. All cases of cancer except non-melanotic skin cancers are reported to the State Cancer Registry by the treating medical specialist. Providing that cancer registration is reliable, as it is in Australia, cancer incidence measures are a more valid indicator of cancer risk than are cancer mortality measures. This is because many persons who get cancer do not die from their cancer, but from other causes. The SIR is calculated in a similar way to the SMR and is age standardised. To calculate SIRs, calculation of "expected" numbers, from national cancer incidence is required.

If the SIR is 1.0 then that means that cases of cancer are occurring in the *Health Watch* cohort at the same rate as they do in the national population. If the SIR is greater than 1.0 then cases of cancer are occurring in the cohort more frequently than they do in the national population. If the SIR is less than 1.0 then cases of cancer are occurring in the cohort less frequently than they do in the national population.

The SMR and SIR are accompanied by "95% confidence intervals". The SMR or SIR as shown is actually a statistical estimate of the "true" ratio. However, the true ratio cannot be known exactly, and the best we can do is to calculate a spread of estimates of the SMR or SIR within which we can be 95% certain that the "true" figure will lie. This spread is called the confidence interval.

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 1 in 20.

The importance of this lies in the interpretation of the SMR or SIR in terms of risk appraisal. Where a ratio is higher than 1.0 then a risk may be present, but if the lower end of the confidence interval extends below 1.0 then it is possible that the real ratio is 1.0 or less and no risk is present. However, when the lower end of a confidence interval is above 1.0 then we can say with some certainty that a risk does exist. This is often described as being a statistically significant result.

When reporting on SMR, SIR, and confidence intervals for cancers, *Health Watch* uses the following terms:

- Where the observed number of cases is higher than the expected number (SMR or SIR greater than 1.0) **and** the lower confidence limit is less than 1.0, it is reported as an **"excess"** for the category. An "excess" is statistically non-significant, and may have arisen by chance alone.

- Where the observed number of cases is higher than the expected number (SMR or SIR greater than 1.0) **and** the lower confidence limit is greater than 1.0, it is reported as a **"statistically significant excess"** for that category. A "statistically significant excess" is unlikely to have arisen by chance alone and is always an important finding.

Summary box

Measures of Comparison - the SMR and SIR

When reading the tables, the SMR or SIR is simply a comparison between the observed number of deaths or cases and the number expected if the Health Watch cohort experienced similar mortality or incidence as the Australian population as a whole. A SMR or SIR of one (1.0) means the observed number of cases in Health Watch is what you would normally expect in any similar group. Below 1.0 probably means Health Watch people are doing better than the average, and above 1.0 means there are more deaths or cases than would be expected.

2.4.2. The RMR and RIR

Health Watch uses internal comparisons to look at the health effects of working in the petroleum industry. Where a measure or ranking of exposure can be obtained a **relative mortality ratio (RMR)** or **relative incidence ratio (RIR)** can be calculated, comparing those who have less exposure to those who have more. Generally, we would expect that if the exposure is causing the effect, then those with more exposure, in time or intensity, would suffer more effect on their health, and this would show up in the health outcomes. This is known to apply, for example, for the number of cigarettes smoked and its outcome in terms of risk of getting lung cancer. It applies for most exposures which create risks to health.

For any particular exposure or category, a "baseline" group is chosen, and represented as having a risk of 1.0. All other exposure groups or ranks are then calculated for risk in comparison with the baseline. The measures of these comparisons are the relative mortality ratio (RMR) when death is the outcome or relative incidence ratio (RIR) when a case of cancer is the outcome.

The "baseline" is usually the least exposed group. For smoking it is people who have never smoked. For hydrocarbon exposures it is office and service workers. 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 baseline group. If the RMR or RIR is greater than 1.0 then deaths or cancers are occurring more frequently than they do in the baseline group. If the RMR or RIR is less than 1.0 then deaths or cancers are occurring less frequently than they do in the baseline group.

These ratios are also standardised for age and 95% confidence limits are given. Again we can be 95% sure that the "real" relative risk lies inside the confidence interval. As these models depend on "large sample" theory for statistical validity, 95% confidence intervals are not given if either of the two categories being compared has fewer than four cases.

Summary box

Measures of Comparison - the RMR and RIR

The RMR and RIR are used in the cohort analysis for internal comparisons between groups within the industry that have different levels of exposure. Comparisons are made relative to the least exposed, or "baseline" category. A RMR or RIR of 1.0 for any group means that the observed number of deaths or cancers is occurring at the same rate as they do in the baseline group. If the RMR or RIR is greater (less) than 1.0 then deaths or cancers are occurring more (less) frequently in that exposure category than in the baseline category. If the lower number in the confidence interval of an RMR or RIR is above 1.0 then this indicates a high result which is unlikely to be just due to chance.

For statistical reasons, confidence intervals are given for the RMR or RIR estimate only when both categories being compared have greater than four cases.

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 reliably done to the same level of detail as for men.

The results come from analyses of various occupational factors and categories, smoking and alcohol. Account is taken of age through standardisation. Diseases and cancer types are grouped into major categories for which comparisons are available from the Australian Bureau of Statistics and State Cancer Registries.

3.1. The Cohort Population

3.1.1. Description of Cohort Population at December 31 1998

There are 16252 males and 1273 females in the *Health Watch* cohort population analysed in this report. This reflects the preponderant employment of males in the industry. The growth of the cohort since 1981 is shown in Figure 2.

Since the 10th Report, 1486 subjects interviewed for the first time in the Fourth Health Watch Survey have been added to the cohort. Approximately one-half of these subjects had commenced employment since 1996; these are not included in the current analyses as they have not yet completed five years in the industry. Some subjects had been employed at the time of previous surveys but were only interviewed for the first time in the Fourth Health Watch Survey; they are included in this analysis. Altogether 615 cohort members are included in this analysis for the first time.

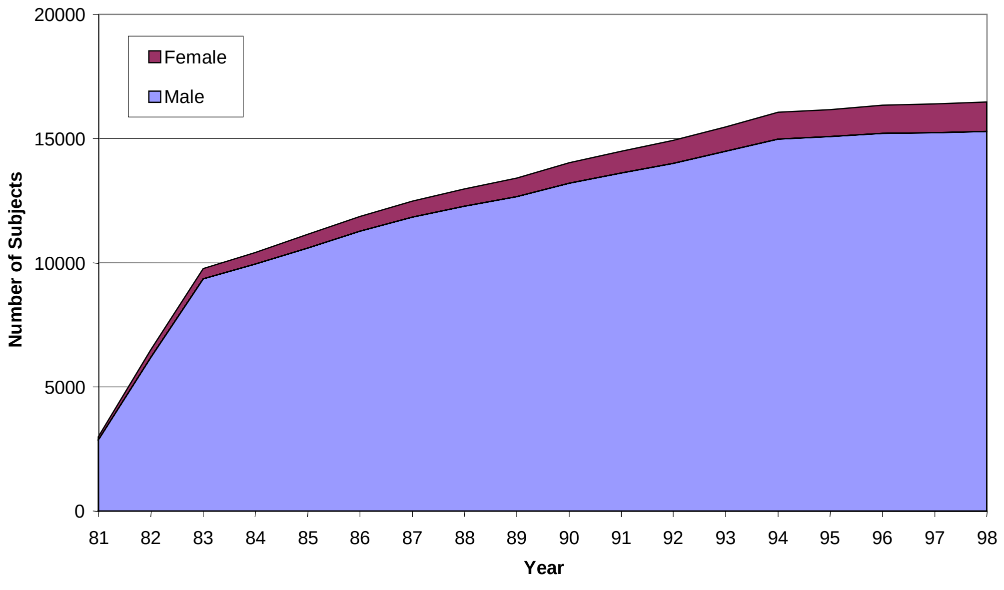

Figure 2: *Growth in the number of subjects in the study population*

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. Each subject completes a person-year of observation for each year since entry into the cohort (5 years from first employment) until death. The number of person-years of observation of the cohort is the sum of the person-years contributed by each cohort member. *Health Watch* has now accumulated 224108 person-years of observation, of which 210865 are in men. The accumulation of person-years by calendar period is shown in Table 1 and Figure 3. The calendar periods listed in Table 1 are used in the standardisation of mortality rates against the Australian Bureau of Statistics death rates.

Table 1: *Person-years of observation by sex*

Sex	Number of Subjects	Person-years of observation 1981-85	1986-90	1991-95	1996-98	Total
Males	16252	33904	59947	70901	46113	210865
Females	1273	1583	3382	4786	3492	13243

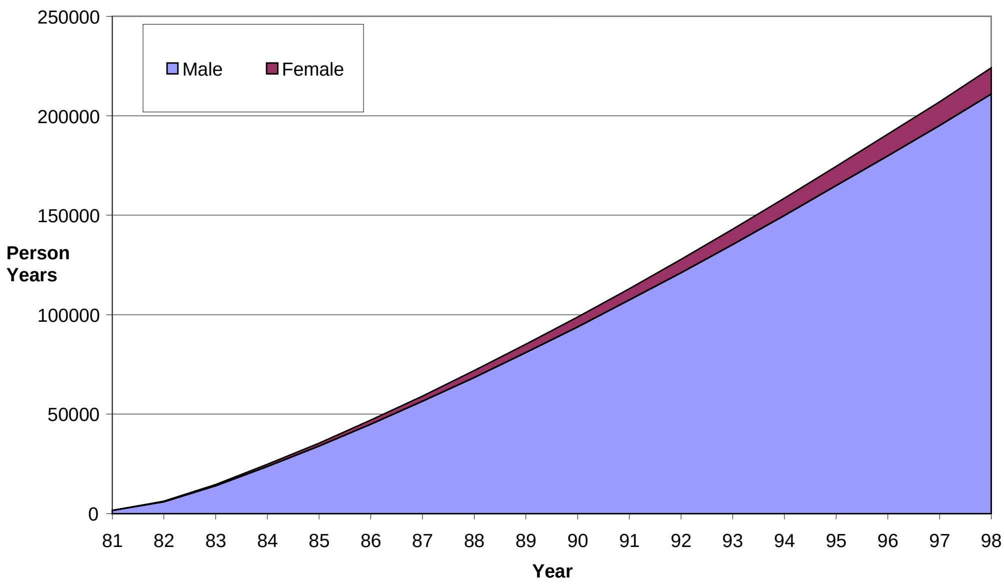

Figure 3: *Person-years of observation*

Figure 4 shows the rate of increase in the accumulation of person-years of observation for male members of the cohort by age. Because the number of new entrants is now relatively small in relation to the whole cohort, the age distribution is moving towards an older population. This factor alone strongly influences the death rate from most non-infectious diseases, as well as increasing the incidence (rate of occurrence in the population) of cancer. Consequently, when estimates are made of the risk of death or disease from any particular cause in the *Health Watch* population compared with the general population, allowance must be made for the fact that the increasing age of the *Health Watch* cohort itself will increase the probability of death or disease such as cancer.

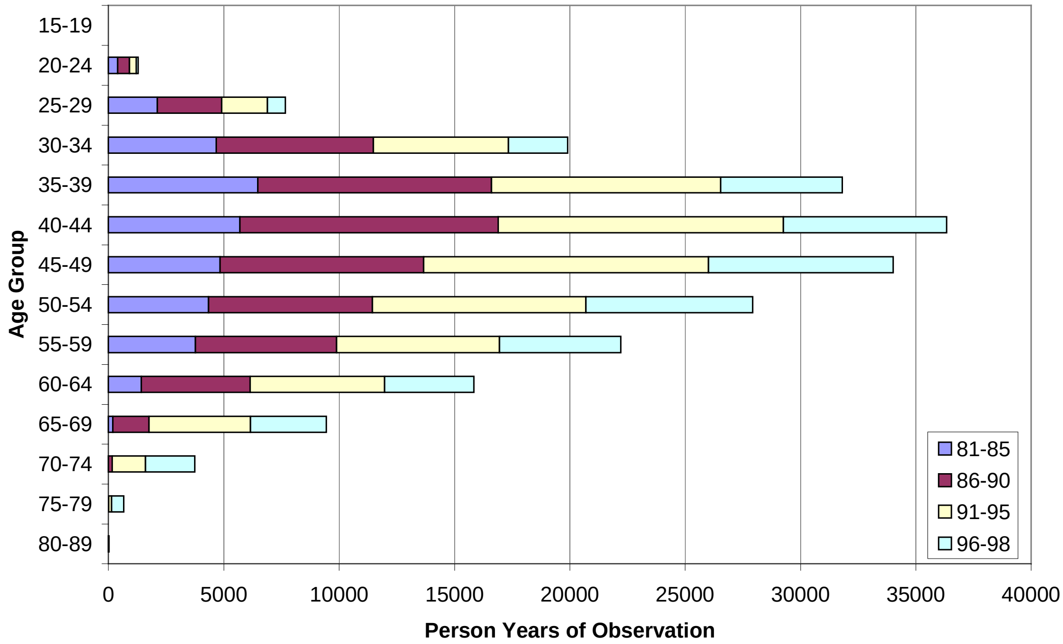

Figure 4: *Person-years of observation by age for the male study population. Bands indicate calendar periods used in calculation of expected numbers for SMR and SIR*

3.2. All-cause Mortality

All cause mortality is a measure of how the *Health Watch* population is dying off as they age compared to the population of Australia. Up to the 31st December 1998, 883 deaths had occurred in the *Health Watch* population since 1981, 865 in men. However, if the men in the *Health Watch* had died off at the rate of the Australian population generally, then 1259.9 deaths would have been expected. Eighteen women had died compared with 29.7 expected.

Standardised mortality ratios (SMRs) have been calculated from these figures, to give an overall view of mortality in the cohort population, compared to the Australian national population, having adjusted for the effects of age and calendar periods (Table 2).

Table 2: *All-cause mortality by sex, standardised for age and calendar period of follow-up*

Sex	Person-Years	Observed	Expected	SMR†	95% C.I.
Males	210865	865	1259.89	0.69	0.64 - 0.73
Females	13243	18	29.68	0.60	0.36 - 0.96

† Test of equal SMR: male:female difference in SMR non-significant

These comparisons with national rates continue to show that the death rate in this workforce is significantly lower than in the general population, after adjusting for age differences and the general increase in life expectancy occurring in the Australian population in recent decades.

This low mortality rate is often noted in working groups and is known as the "healthy worker effect".[4,5] As the name implies, those who are employed generally have a greater life expectancy than the average for the total national population with which they are compared. The national Australian population includes several disadvantaged groups, for example, the unemployed and the chronically sick, who are known to have poor health outcomes based on measures such as standardised mortality rates. In the Australian petroleum industry this effect, as indicated by the low SMR figures of the *Health Watch* cohort, is very marked, with SMRs for men in the industry comparable to the lowest recorded in overseas occupational studies.

It is generally believed that the healthy worker effect is a selection effect, that is, people in good health are more likely to obtain employment in a relatively well-paid industry such as the petroleum industry. Health status also tends to mirror educational levels, so that people with a relatively higher education level will more readily obtain secure employment, so that those in secure employment are also those members of the population who tend to enjoy relatively good health.

Another factor likely to favour a healthy population in this industry is their ready access to medical services. Access to diagnostic and treatment services for employees of major petroleum companies in Australia is probably as high as anywhere for a blue-collar group. This may be particularly important in the case of cancer, which is discussed later in this report.

The SMR for men is significantly low compared with the Australian male population, ie 0.69 (95% confidence interval 0.64-0.70). However this is higher than the 60% estimate found in the previous *Health Watch* report. The narrowing of the healthy worker effect over time is a common finding as cohorts age.

The all-cause SMR for women is also significantly low at 0.60. This estimate is based on small numbers – only 18 deaths – and is reflected in the wide 95% confidence interval of 0.36-0.96 There is no statistical difference between death rate figures for women and men.

3.3. Results for Women

The ability of *Health Watch* to carry out analysis of the data for women continues to be limited because of the small number of women in the study population.

3.3.1. Mortality by Major Cause for Females

Table 3 shows the mortality by separate major cause for females. Because of the small number of women in the industry, cancer and ischaemic heart disease are the only major disease categories where more than one death has been recorded. Mortality from these causes and overall mortality is not significantly different from expected values for the general female population.

Table 3: *Mortality by major cause, females*

Cause	ICD9	Observed	Expected	SMR	95% C.I.
Cancer	140 - 208	14	13.90	1.01	0.55 - 1.69
Ischaemic heart disease	410 - 414	3	3.74	0.80	*
All other causes		1	12.04	0.08	*
All causes	001 - 999	18	29.68	0.60	0.36 - 0.96

3.3.2. Cancer in Females

The overall and site-specific cancer incidence rates in females are shown in Table 4. Overall the standardised incidence ratio (SIR) shows a small increase of marginal statistical significance (SIR = 1.33, 95% confidence interval 0.98-1.77), based on 47 cases.

Table 4: *Cancer incidence by major anatomical site, females*

Malignant neoplasm of	ICD9	Observed	Expected	SIR	95% C.I.
Colon	153	4	2.50	1.60	0.44 - 4.10
Melanoma	172	12	4.52	2.65	1.37 - 4.63
Breast	174	13	12.03	1.08	0.58 - 1.85
Cervix	180	3	1.93	1.55	*
Bladder	188	3	0.43	7.02	*
Other		12	13.96	0.86	0.44 - 1.50
All malignant (excluding 173)		47	35.37	1.33	0.98 - 1.77

Most of the excess can be accounted for by the high incidence of melanoma – 12 cases compared with an expected rate of 4.5. There has been a similar finding in the case of males, (discussed in Section 4.3). This may be caused by a high reporting rate rather than a true increase in incidence rate. This is particularly likely to be so in the case of female workers, since in this industry few if any women are subject to any of the occupational exposures likely to cause or accelerate the onset of this condition.

The cancer data for females cannot be divided reliably to show the distribution by workplace types or time variables, due to the small numbers, nor analysed by any exposure measures, as nearly all the observed person-years of exposure for women in *Health Watch* are in the lowest exposure categories.

Summary box

Results for females in Health Watch

The proportion of women in the Health Watch program remains very small and this prevents much detailed analysis. Women in the industry have death rates which do not differ from women in Australia generally. Cancer incidence is slightly elevated, due principally to a high melanoma rate, which may reflect a high reporting rate rather than a true increase in incidence.

3.4. Results For Men

3.4.1. All-cause Mortality and Time Relationships

Internal comparisons have been carried out for all cancers combined to identify any association with the era of first employment in the industry, duration of employment in the industry, and time lapse between first employment in the industry and death. All analyses have been adjusted for age and calendar period of follow-up.

All-cause mortality by period of first employment

Table 5: *All-cause mortality by period of first employment, adjusted for age and calendar period of follow-up*

Period of first employment	Person-years	Deaths	RMR†	95% C.I.
Post - 1975	99 866	149	1.00	
1965 - 74	69 594	252	1.12	0.90 - 1.41
1955 - 64	28 204	290	1.43	1.11 - 1.84
Pre - 1954	13 201	174	1.27	0.96 - 1.69

† Test of heterogeneity: P = 0.0219
Test for trend: P = 0.1763

The relative mortality rate for all causes combined is higher for men who entered the industry at all prior periods compared with those who entered after 1975. The mortality rate is significantly higher for those who entered in the period 1955-64 compared with those who entered after 1975. The relatively high mortality for those employed in the earlier periods may be due to the longer follow-up times since their first employment. As discussed in Section 3.4.3 a low mortality rate is not uncommon in occupational cohorts, and is attributed to a “healthy worker” effect. This finding is commonly found to decrease ie a rising mortality rate, as cohorts are followed for increasing time (ie the SMR approaches unity with increasing follow-up time). On this basis those *Health Watch* subjects employed earlier, and who are likely to have been followed up longer, will have higher relative mortality rates. (However this comparison does not constitute an explanation of *why* relative mortality should increase with follow-up time.)

The trend towards a falling relative mortality rate for later entrants into the industry is not statistically significant. Thus the higher relative mortality rates in earlier entrants could be a chance occurrence. However, alteration in smoking patterns could be a contributing factor. There is evidence that the fall in smoking prevalence in Australian males over recent decades has varied between occupational categories.[3,6] If successive entrants to the oil industry had reduced rates of smoking in comparison with other men of the same age, a reducing relative mortality over time could result.

All-cause mortality by duration of employment

Table 6: *All-cause mortality by duration of employment, adjusted for age and calendar period of follow-up*

Length of employment	Person-years	Deaths	RMR†	95% C.I.
5 - 9 years	53335	63	1.00	
10 - 14 years	51708	118	1.23	0.89 - 1.70
15 - 19 years	39878	121	1.09	0.78 - 1.52
20 - 24 years	26693	121	1.11	0.79 - 1.56
≥ 25 years	39251	442	1.47	1.08 - 2.02

† Test of heterogeneity: P = 0.0077
Test for trend: P = 0.1497

As shown in Table 6, the mortality rate from all causes combined is also higher in all categories of duration of employment greater than 9 years. The trend for increasing relative mortality according to duration of employment is not statistically significant. The findings are similar to those relating to period of entering the industry and the cause or causes of this finding may be similar, ie related to a declining intake of smokers relative to the general population.

All-cause mortality by time since first employment

Table 7: *All-cause mortality by time since first employment, adjusted for age and calendar period of follow-up*

Time since first employment	Person-years	Deaths	RMR†	95% C.I.
5 - 9 years	41178	41	1.00	
10 - 14 years	46876	78	1.21	0.81 - 1.80
15 - 19 years	41581	101	1.18	0.79 - 1.77
20 - 24 years	30613	112	1.12	0.74 - 1.70
≥ 25 years	50618	533	1.39	0.93 - 2.07

† Test of heterogeneity: P = 0.2285
Test for trend: P = 0.1457
Total person-years not equal to the sum of the displayed figures due to rounding

As shown in Table 7, there is a similar positive but weak association between relative all-cause mortality and increasing time between entry into the industry and time of death.

3.4.2. Mortality by Major Cause

The SMRs for major categories of cause are shown in Table 8. In all major categories the observed number of deaths is less than expected, and so all SMRs are below 1.0. The upper limits of confidence intervals are all below unity (1.0) indicating that it is most unlikely that any major disease category is in excess in the male cohort.

Table 8: *Mortality by major cause*

Cause	ICD-9	Observed	Expected	SMR	95% C.I.
Cancer (Malignant)	140 - 208	345	425.31	0.81	0.73 - 0.90
Ischaemic heart disease	410 - 414	228	320.01	0.71	0.62 - 0.81
Stroke	430 - 438	37	61.57	0.60	0.42 - 0.83
Respiratory disease	460 - 519	52	76.89	0.68	0.51 - 0.89
Other diseases of the digestive system	570 - 579	21	40.21	0.52	0.32 - 0.80
Accidents and violence	800 - 999	88	136.14	0.65	0.52 - 0.80
All other causes		94	199.77	0.47	0.38 - 0.58
All causes	001 - 999	865	1259.89	0.69	0.64 - 0.73

Ischaemic heart disease mortality

Ischaemic heart disease mortality, based on 228 male deaths, is low with an SMR of 0.71 and with the upper limit of the confidence interval at 0.81. This low death rate would suggest that the incidence of ischaemic heart disease itself in this cohort is also low, and comparable with that in the more advantaged groups in Australian society. As discussed later in this report, the prevalence of smoking in this cohort is very similar to that of the Australian population. It is likely however that there are important differences between the smoking habits of the smokers in the *Health Watch* cohort and the smokers in the general population. The occurrence of heart disease depends not only on whether the person does or does not smoke, but on factors such as the number of cigarettes smoked, age at starting and tar content. Variations in these factors could account for differences in heart disease rates even tough the actual smoking prevalence is the same in the *Health Watch* cohort as in the general population.

Accidental death

Accidental death, which by definition includes homicide and suicide, has occurred at a significantly lower rate compared with the general male population (SMR 0.65, 95% confidence interval 0.52 - 0.80).

3.4.3. Cancer in Males

Cancer incidence and mortality

The cases (incidence) of cancer and the death rates (mortality) from cancer are dealt with together in this section. Cancers are classified under the International Classification of Diseases, Revision 9, and the International Classification of Diseases for Oncology (ICD9, ICDO) by morphological type (ie, where it arises in the body) and/or by histology (cell type). Cancers occurring in *Health Watch* members are analysed according to workplace type, smoking effects and exposure to hydrocarbons.

Tables 9 and 9a show the cancer incidence and cancer mortality in the *Health Watch* population.

The standardised incidence ratio (SIR) for cancer in males is slightly elevated at 1.04, but the increase is not statistically significant. On the other hand, the standardised mortality ratio (SMR) for cancer in males, 0.81, is significantly low in comparison with the general male population (95% confidence interval 0.73-0.90).

Table 9: *All-site cancer incidence, males and females*

Sex	Person-years	Observed	Expected	SIR	95% C.I.
Males	180493	832	801.32	1.04	0.97 - 1.11
Females	10914	47	35.37	1.33	0.98 - 1.77

Table 9a: *All-site cancer mortality, males and females*

Sex	Person-years	Observed	Expected	SMR	95% C.I.
Males	210865	345	425.17	0.81	0.73 - 0.90
Females	13243	14	13.90	1.01	0.55 - 1.69

The low SMR for cancer is probably a reflection of the so-called "healthy worker effect". As discussed in the section on all-cause mortality, this is believed to be largely a selection effect, that is, people in good health are more likely to obtain secure employment and to have a longer life expectancy as a group compared with the general population. Another possible factor is the ready access to medical services for employed workers.

The latter factor may be particularly important in the low cancer mortality in this industry. A critical factor in survival from cancer is early presentation, which increases the chance of cure and survival time. Regular health surveillance and health promotion activities, such as those in the petroleum industry, will raise awareness of early warning signs of cancer and increase the probability of early presentation.

Indeed, it is of interest that the numerous epidemiological studies which demonstrated the "healthy worker effect" were not studies of disease incidence but of mortality. The simultaneous presentation of cancer incidence and cancer mortality studies by *Health Watch* indicates that a healthy worker effect is clearly demonstrable when mortality is used as a marker but not when cancer incidence is used. This raises the intriguing possibility that the healthy worker effect is in fact not the consequence of a reduced disease incidence but of affected individuals receiving early investigation and treatment.[7]

It should be pointed out that the cancer incidence and cancer mortality data presented in Tables 9 and 9a are not fully comparable, as the cancer analysis has been updated only to the end of 1996, whereas the mortality analysis goes up to the end of 1998 (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 whereas cancer incidence is not.

The finding is highly significant in terms of public health. A prevailing belief has been that provision of health services and medical services is of less importance in maintaining public health than other measures such as nutrition, secure water supplies and a clean environment. These findings suggest that at least in a population such as the petroleum industry workforce, maintenance of health and medical services is crucial.

Site-specific cancer incidence and mortality are shown in Tables 10 and 11. They show cancer incidence and cancer mortality for different cancer sites in the body as classified in ICD9. The tables list the number of cases or deaths of the particular cancer observed in the *Health Watch* population, the number expected, and the calculated standardised incidence and mortality ratios.

Table 10: *Cancer incidence by major anatomical site*

Malignant neoplasm of:	ICD-9	Observed	Expected	SIR	95% C.I.
Lip	140	21	20.19	1.04	0.64 - 1.59
Tongue	141	8	7.88	1.02	0.44 - 2.00
Salivary Gland	142	3	2.54	1.18	*
Oropharynx	146	2	5.58	0.36	*
Oesophagus	150	7	12.06	0.58	0.23 - 1.20
Stomach	151	26	25.03	1.04	0.68 - 1.52
Colon	153	66	70.10	0.94	0.73 - 1.20
Rectum	154	49	49.04	1.00	0.74 - 1.32
Liver	155	6	7.29	0.82	0.30 - 1.79
Gallbladder	156	5	4.47	1.12	0.36 - 2.61
Pancreas	157	16	15.57	1.03	0.59 - 1.67
Larynx	161	14	15.51	0.90	0.49 - 1.51
Lung	162	76	114.36	0.66	0.52 - 0.83
Pleura	163	12	6.27	1.92	0.99 - 3.35
Connective tissue	171	6	7.57	0.79	0.29 - 1.72
Melanoma	172	144	95.11	1.51	1.28 - 1.78
Prostate	185	138	118.60	1.16	0.98 - 1.37
Testis	186	13	11.56	1.12	0.60 - 1.92
Bladder	188	47	34.31	1.37	1.01 - 1.82
Kidney	189	28	25.12	1.11	0.74 - 1.61
Eye	190	5	2.77	1.81	0.59 - 4.21
Brain & Nervous System	191 - 192	18	17.40	1.03	0.61 - 1.63
Non-Hodgkin's lymphoma	200 - 202	34	34.36	0.99	0.69 - 1.38
Multiple myeloma	203	15	8.91	1.68	0.94 - 2.78
Leukaemia	204 - 208	30	19.92	1.50	1.02 - 2.15
Lymphoid leukaemia	204	13	8.76	1.48	0.79 - 2.54
Myeloid leukaemia	205	13	9.60	1.35	0.72 - 2.32
Other leukaemia	206 - 208	4	1.55	2.58	0.70 - 6.60
Other & unspecified sites		43	69.81	0.62	0.45 - 0.83
All malignant (excluding 173)		832	801.32	1.04	0.97 - 1.11

Table 11: *Cancer mortality by major anatomical site*

Malignant neoplasm of:	ICD-9	Observed	Expected	SMR	95% C.I.
Oesophagus	150	10	14.43	0.69	0.33 - 1.27
Stomach	151	15	18.16	0.83	0.46 - 1.36
Colon	153	33	41.31	0.80	0.55- 1.12
Rectum	154	14	16.85	0.83	0.45 - 1.39
Liver	155	6	9.23	0.65	0.24 - 1.41
Gallbladder	156	3	2.69	1.12	*
Pancreas	157	12	18.11	0.66	0.34 - 1.16
Larynx	161	4	6.50	0.62	0.17 - 1.58
Lung	162	76	117.65	0.65	0.51 - 0.81
Pleura	163	7	4.18	1.68	0.67 - 3.45
Connective tissue	171	3	2.70	1.11	*
Melanoma	172	15	16.68	0.90	0.50 - 1.48
Non-melanotic skin	173	2	4.44	0.45	*
Prostate	185	22	25.48	0.86	0.54 - 1.31
Bladder	188	8	8.13	0.98	0.43 - 1.94
Kidney	189	14	11.25	1.24	0.68- 2.09
Brain	191	17	17.37	0.98	0.57 - 1.57
Unspecified	199	26	23.64	1.10	0.72 - 1.61
Non-Hodgkin's lymphoma	200 - 202	13	17.11	0.76	0.40 - 1.30
Multiple myeloma	203	11	6.41	1.72	0.86 - 3.07
Leukaemia	204 - 208	16	13.81	1.16	0.66 - 1.88
Lymphoid leukaemia	204	4	3.91	1.02	0.28 - 2.62
Myeloid leukaemia	205	10	9.19	1.09	0.52 - 2.00
Other leukaemia	206 - 208	2	0.72	2.79	*
Other sites		18	28.77	0.63	0.37 - 0.99
All malignant	140 - 208	345	425.17	0.81	0.73 - 0.90

3.4.4. Cancer and Time Relationships

Cancer incidence and mortality according to period of first employment

Table 12 shows that when compared to the baseline category of being first employed after 1975, categories of people employed before 1965 have a relative increase in cancer incidence. There is a statistically significant trend towards increased cancer incidence with earlier periods of first employment in the industry. Mortality rates are also higher in earlier periods of initial employment in the industry, but the trend is not statistically significant.

Table 12: *Cancer incidence and mortality by period of first employment, adjusted for age and calendar period of follow-up*

Period of first employment	Incidence Cancers	RIR†	95% C.I.	Mortality Deaths	RMR†	95% C.I.
Post - 1975	155	1.00		54	1.00	
1965 - 74	254	1.24	0.99 - 1.55	99	1.11	0.77 - 1.60
1955 - 64	262	1.61	1.24 - 2.08	122	1.47	0.99 - 2.19
Pre - 1954	161	1.56	1.16 - 2.09	70	1.27	0.81 - 1.99

†Test for trend P = 0.00131 †Test for trend: P = 0.1821

Cancer incidence and mortality by duration of employment

Table 13 shows relative cancer incidence and mortality by duration of employment. Both cancer incidence and cancer mortality increase with increasing duration of employment.

Table 13: *Cancer incidence and mortality by duration of employment, adjusted for age and calendar period of follow-up*

Length of employment	Incidence Cancers	RIR†	95% C.I.	Mortality Deaths	RMR†	95% C.I.
5 - 9 years	80	1.00		15	1.00	
10 - 14 years	136	1.17	0.88 - 1.56	54	2.19	1.21 - 3.95
15 - 19 years	102	0.81	0.59 - 1.10	38	1.28	0.68 - 2.41
20-24 years	121	1.05	0.76 - 1.43	55	1.85	1.00 - 3.43
≥25 years	393	1.32	0.98 - 1.77	183	2.22	1.23 - 4.00

†Test for trend P = 0.0225 †Test for trend: P = 0.0251

Cancer incidence and mortality by time since first employment

Table 14 shows relative cancer incidence and mortality by time elapsed from first employment to date of diagnosis or death. There is no relationship between cancer incidence and time since first employment. Cancer mortality in categories employed more than 10 years prior to diagnosis is increased relative to those whose cancer arose within 10 years of joining the industry. However there is no statistically significant trend with increasing time since first employment.

Table 14: *Cancer incidence and mortality by time since first employment, adjusted for age and calendar period of follow-up)*

Time since first employment	Incidence			Mortality		
	Cancers	RIR†	95% C.I.	Deaths	RMR†	95% C.I.
5 - 9 years	55	1.00		8	1.00	
10 - 14 years	101	1.15	0.82 - 1.62	35	2.51	1.14 - 5.54
15 - 19 years	100	0.93	0.65 - 1.32	37	1.90	0.84 - 4.29
20 - 24 years	122	1.09	0.76 - 1.56	49	2.03	0.90 - 4.59
≥25 years	454	1.20	0.84 - 1.70	216	2.21	0.99 - 4.91

†Test for trend P = 0.2471 †Test for trend: P = 0.3674

The time relationships give some indication that those who joined the industry prior to about 1965 may have had a slightly increased risk of dying younger and of getting cancer compared to those who joined the industry at a later date. Moreover the increasing incidence and mortality with increasing duration of employment are suggestive of a work-related factor or factors. The significance of these findings is uncertain, as the overall cancer experience seems to be virtually identical with the Australian population. Since overall cancer incidence is an arbitrary combination of a large number of different diseases, a valid interpretation is better obtained by consideration of individual cancer types (Section 4 of this report).

Summary box

Cancer

The chance of getting cancer is the same for men in this industry as for other Australians. Those who worked in the industry in earlier times may have been at greater risk for cancer than those who entered the industry more recently. Cancer incidence also shows a tendency to increase with increasing duration of employment in the industry. However, the significance of this finding is unclear since the overall cancer incidence in the Health Watch population is the same as that of the general male population. This subject is further considered in relation to specific cancer types in Section 4 of this report.

3.4.5. Workplace Type and Health Outcomes

Analyses were undertaken for the five principal workplace types – refineries, terminals, airports, onshore production and offshore production. As shown in Figure 5, most of the person-time of the data is weighted strongly towards refineries and terminals.

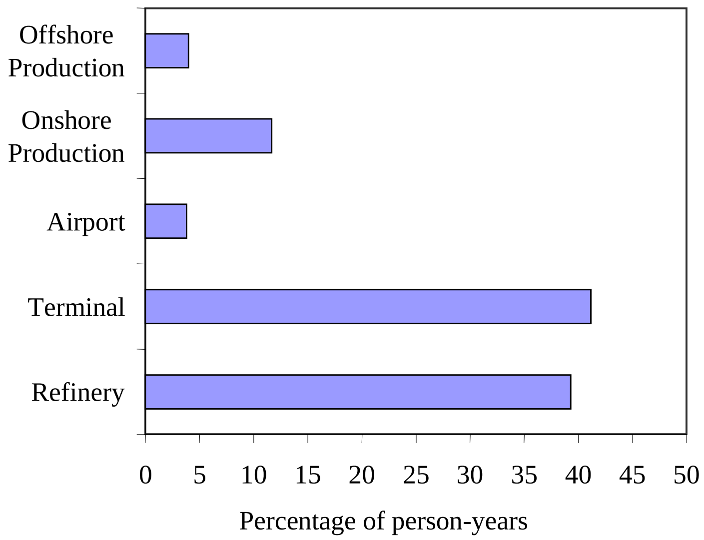

Figure 5: *Percentage of person-years contributed by each workplace type*

The all-cause mortality (Table 15), and ischaemic heart disease mortality (Table 16) show no statistically significant variation with different workplace types. All workplace types have a standardised mortality ratio well below 1.0.

Table 15: *All-cause mortality by workplace type*

Workplace type	Person-years*	Observed	Expected	SMR	95% C.I.
Refinery	82913	355	528.12	0.67	0.60 - 0.75
Terminal	86821	410	556.34	0.74	0.67 - 0.81
Airport	8063	29	51.87	0.56	0.37 - 0.80
Onshore production	24651	56	95.61	0.59	0.44 - 0.76
Offshore production	8415	15	27.93	0.54	0.30 - 0.89
	210865	865	1259.89	0.69	0.64 - 0.73

*Total person-years not equal to the sum of the displayed figures due to rounding

Table 16: *Ischaemic heart disease mortality by workplace type*

Workplace type	Person-years*	Observed	Expected	SMR	95% C.I.
Refinery	82913	100	135.89	0.74	0.60 - 0.90
Terminal	86821	112	143.61	0.78	0.64 - 0.94
Airport	8063	3	13.39	0.22	*
Onshore production	24651	10	21.21	0.47	0.23 - 0.87
Offshore production	8415	3	5.91	0.51	*
	210865	228	320.01	0.71	0.62 - 0.81

*Total person-years not equal to the sum of the displayed figures due to rounding

Table 17 shows the incidence of cancer in the different workplace types. All 5 categories of workplace type show total cancer risks which are no different from the general population.

Total cancer mortality was significantly reduced for the largest categories of refinery and terminal operators. The other categories of workplace type showed no significant difference from population levels.

Table 17: *Cancer incidence by workplace type*

Workplace type	Person-years*	Observed	Expected	SIR	95% C.I.
Refinery	70964	332	333.11	1.00	0.89 - 1.11
Terminal	75280	391	357.27	1.09	0.99 - 1.21
Airport	6970	36	33.40	1.08	0.75 - 1.49
Onshore production	20179	52	59.73	0.87	0.65 - 1.14
Offshore production	7099	21	17.80	1.18	0.73 - 1.80
	180493	832	801.32	1.04	0.97 - 1.11

*Total person-years not equal to the sum of the displayed figures due to rounding

Table 18: *Cancer mortality by workplace type*

Workplace type	Person-years*	Observed	Expected	SMR	95% C.I.
Refinery	82913	144	178.41	0.81	0.68 - 0.95
Terminal	86821	157	190.20	0.83	0.70 - 0.97
Airport	8063	15	17.90	0.84	0.47 - 1.38
Onshore production	24651	22	30.20	0.73	0.46 - 1.10
Offshore production	8415	7	8.60	0.81	0.33 - 1.68
	210865	345	425.17	0.81	0.73 - 0.90

*Total person-years not equal to the sum of the displayed figures due to rounding

Summary box

Health and workplace type

The health of employees as measured from the Health Watch results does not differ much between the various types of workplaces in the industry, such as upstream production sites and downstream refineries, terminals and distribution sites.

Generally the chances of dying at any age, or of getting cancer or heart disease are very similar no matter where Health Watch people work, and generally compare favourably with the rates in all Australian men.

Within that overall good news, there is a risk of getting certain types of cancer, and Health Watch researches and reports on this in more detail. These cancers are discussed in Section 4 of this report.

3.4.6. Total Hydrocarbons Exposure and Health Outcomes

Tables 19 to 26 show the analyses of all-cause mortality, ischaemic heart disease mortality, total cancer incidence and total cancer mortality according to hydrocarbon exposure. All four outcomes are analysed both according to the highest-hydrocarbon ranking job ever held, and the hydrocarbon ranking of the job held longest. All comparisons are adjusted for variations in age and the proportion of current smokers.

Only all-cause mortality, based on the hydrocarbon ranking of the job held longest, showed a significant increase with increasing exposure (Table 20). In the absence of any such trend in either of the two major categories of disease leading to mortality – heart disease and cancer – it is unlikely that this finding is of any importance. In the absence of any real effect, such a finding from chance alone is not unexpected in one out of 8 such tables.

Table 19: *All-cause mortality by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age and smoking*

Exposure Category	Person-years*	Deaths	RMR†	95% C.I.
1	40289	170	1.00	
2	18862	41	0.95	0.67 - 1.34
3	2283	8	0.93	0.46 - 1.89
4	95785	435	1.28	1.07 - 1.53
5	7665	21	0.94	0.60 - 1.48
6	33612	142	1.08	0.86 - 1.36
7	12338	48	1.11	0.81 - 1.54

†Test for trend: P = 0.2163
*Total person-years not equal to the sum of the displayed figures due to rounding.
Note: 6 members (33 person-years) have been excluded from this analysis since job details for all of their jobs are missing

Table 20: *All-cause mortality by total hydrocarbon exposure (based on total hydrocarbon ranking of longest job ever held), adjusted for age and smoking*

Exposure Category	Person-years*	Deaths	RMR†	95% C.I.
1	54213	197	1.00	
2	19949	43	0.97	0.69 - 1.35
3	3539	10	0.86	0.45 - 1.62
4	88439	428	1.32	1.12 - 1.57
5	5628	16	0.84	0.51 - 1.41
6	29895	136	1.13	0.91 - 1.41
7	6039	34	1.30	0.91 - 1.88

†Test for trend: P = 0.0341
*Total person-years not equal to the sum of the displayed figures due to rounding.
Note: 232 members (3164 person-years have been excluded from this analysis since the job details for the longest job ever held are missing.

Table 21: *Ischaemic heart disease mortality by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age and smoking*

Exposure Category	Person-years*	Deaths	RMR†	95% C.I.
1	40289	45	1.0	
2	18862	6	0.56	0.24 - 1.31
3	2283	2	0.84	*
4	95785	124	1.39	0.99 - 1.96
5	7665	4	0.69	0.25 - 1.92
6	33612	34	0.97	0.62 - 1.51
7	12338	13	1.16	0.63 - 2.16

†Test for trend: P = 0.50141
*Total person-years not equal to the sum of the displayed figures due to rounding.
Note: 6 members (33 person-years) have been excluded from this analysis since job details for all of their jobs are missing.

Table 22: *Ischaemic heart disease mortality by total hydrocarbon exposure (based on total hydrocarbon ranking of longest job ever held), adjusted for age and smoking*

Exposure Category	Person-years*	Deaths	RMR†	95% C.I.
1	54213	52	1.00	
2	19949	7	0.64	0.29 - 1.41
3	3539	3	0.96	*
4	88439	118	1.39	1.00 - 1.92
5	5628	2	0.40	*
6	29895	33	1.02	0.66 - 1.58
7	6039	12	1.75	0.93 - 3.28

†Test for trend: P = 0.1871
*Total person-years not equal to the sum of the displayed figures due to rounding.
Note: 232 members (3164 person-years) have been excluded from this analysis since the job details for the longest job ever held were missing.

Table 23: *Cancer incidence by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age and smoking*

Exposure Category	Person-years*	Cancers	RIR†	95% C.I.
1	34615	185	1.00	
2	15504	45	0.98	0.71 - 1.37
3	1980	8	0.86	0.42 - 1.74
4	82044	373	1.02	0.85 - 1.22
5	6564	27	1.07	0.71 - 1.60
6	29099	146	1.07	0.86 - 1.34
7	10663	48	1.05	0.76 - 1.45

†Test for trend: P = 0.4912
*Total person-years not equal to the sum of the displayed figures due to rounding
Note: 5 members (23 person-years) have been excluded from this analysis since job details for all of their jobs were missing.

Table 24: *Cancer mortality by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age and smoking*

Exposure Category	Person-years*	Deaths	RMR†	95% C.I.
1	40289	73	1.00	
2	18862	18	1.02	0.61 - 1.72
3	2283	2	0.54	*
4	95785	174	1.21	0.92 - 1.60
5	7665	11	1.16	0.61 - 2.19
6	33612	51	0.91	0.64 - 1.31
7	12338	16	0.88	0.51 - 1.51

†Test for trend: P = 0.8254
*Total person-years not equal to the sum of the displayed figures due to rounding.
Note: 6 members (33 person-years) have been excluded from this analysis since job details for all of their jobs are missing.

Table 25: *Cancer incidence by total hydrocarbon exposure (based on total hydrocarbon ranking of longest job ever held), adjusted for age and smoking*

Exposure Category	Person-years*	Cancers	RIR†	95% C.I.
1	46544	218	1.00	
2	16402	43	0.91	0.65 - 1.26
3	3058	12	0.94	0.53 - 1.69
4	75834	369	1.06	0.90 - 1.25
5	4829	20	0.94	0.60 - 1.49
6	25883	135	1.08	0.87 - 1.34
7	5241	29	1.05	0.72 - 1.55

†Test for trend: P = 0.3862
*Total person-years not equal to the sum of the displayed figures due to rounding.
Note: 231 members (2702 person-years) have been excluded from this analysis since the job details for the longest job ever held were missing

Table 26: *Cancer mortality by total hydrocarbon exposure (based on total hydrocarbon ranking of longest job ever held), adjusted for age and smoking*

Exposure Category	Person-years*	Deaths	RMR†	95% C.I.
1	54213	81	1.00	
2	19949	18	1.04	0.62 - 1.74
3	3539	2	0.42	*
4	88439	177	1.34	1.03 - 1.75
5	5628	9	1.15	0.58 - 2.29
6	29895	48	0.97	0.68 - 1.39
7	6039	10	0.94	0.48 - 1.80

†Test for trend: P = 0.6053
*Total person-years not equal to the sum of the displayed figures due to rounding.
Note: 232 members (3164 person-years) have been excluded from this analysis since the job details for the longest job ever held were missing.

3.5. Smoking and alcohol

3.5.1. Smoking Status

The smoking status of each member of the cohort population is based on smoking habit reported at initial and later interviews with information at the last interview being given prominence. After retirement or leaving the industry, additional information has been derived from postal surveys of all retired and resigned members carried out during 1994, 1996 and 1999 in combination with the health letter. For the first time the analysis includes a separate category for subjects who have only smoked cigars and/or a pipe.

The crude prevalence rate for currently smoking is 29.4%. When directly standardised to the latest survey of Australian smoking habits,[3] taking the age structure into account, the *Health Watch* male smoking rate is 24.1% compared with the Australian population rate of 28.2%. On this basis the age-specific smoking prevalences are considered to be very similar to those found in the Australian national population. Figure 6 compares the percentage of current smokers by age in the *Health Watch* and Australian male populations. Figure 7 shows the smoking status of the *Health Watch* population. (It should be noted that Figure 6 is reproduced from the 10th Health Watch report, in which the national smoking data are based on 1995 estimates, and the *Health Watch* smoking data are based on data current at the time of preparation of that report. It has not been possible to update the figure, as there are no updates of national data available. Figure 7 and all analyses in this Report are based on *Health Watch* smoking data current at the most recent contact, ie Fourth Survey or 1999 Health Letter.)

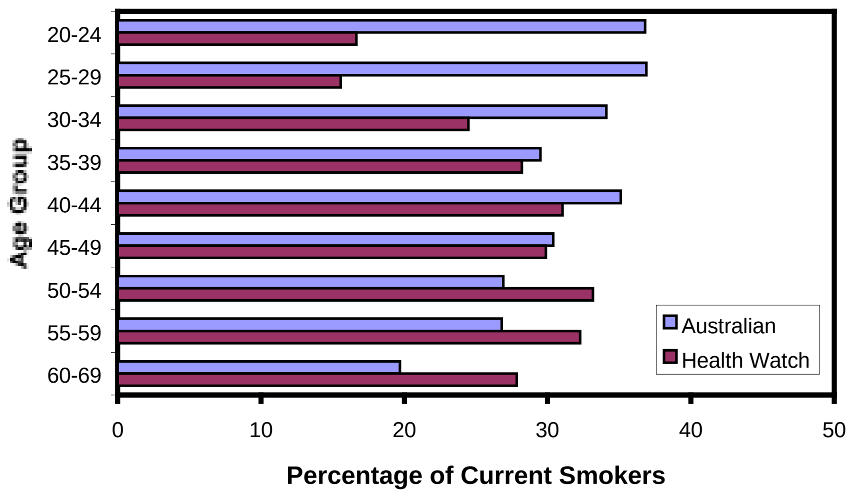

Figure 6: *Comparison of percentage of current smokers by age in the Health Watch and Australian male populations*

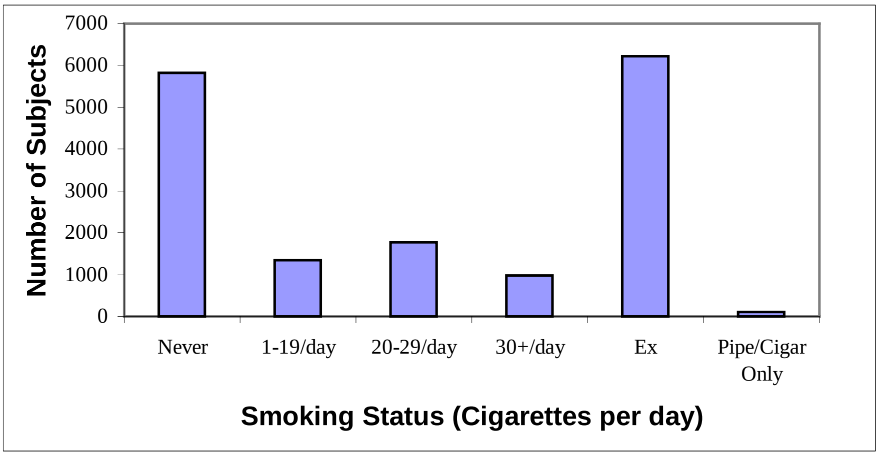

Figure 7: *Smoking status of the Health Watch male study population*

3.5.2. Smoking and all-cause mortality

There is clear evidence of the adverse effects of smoking on the *Health Watch* population. Those who have never smoked enjoy better health and longer life than those who smoke. Non-smokers have been compared to those who did smoke but have quit, and to those who are now smoking, to show the relative risk. The measures are adjusted for age and allow for the declining death rates in the Australian population over recent decades.

In Table 27 the relative mortality ratios 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. People smoking up to 19 cigarettes a day have double 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 is a more than 2½-fold increase in risk, and a trebling of risk above 30 per day. There is no overall increase in risk for ex-smokers. The trend for increasing age-adjusted mortality with increasing smoking level is highly statistically significant.

Table 27: *All-cause mortality by smoking category, adjusted for age and calendar period*

Smoking category	Person-years	Deaths	RMR†	95% C.I.
Never	71896	186	1.00	
1 - 19 / day	16678	90	2.02	1.57 - 2.59
20 - 29 / day	23046	167	2.68	2.18 - 3.31
30+ / day	13001	113	3.28	2.59 - 4.15
Ex-smoker	84885	300	0.97	0.81 - 1.17
Pipe/cigar only	1359	9	2.07	1.06 - 4.03

† Test of heterogeneity: P < 0.0001
Test for trend among current smokers P < 0.0005

3.5.3. Smoking and Cancer

Tables 28 and 29 show the relationship between total cancer incidence and total cancer mortality and smoking. As with all-cause mortality, both of these outcomes show a significant increase with increasing tobacco use, although the trend is not quite as great as for all-cause mortality.

Table 28: *Cancer incidence by smoking category adjusted for age and calendar period*

Smoking category	Person-years*	Cancers	RIR†	95% C.I.
Never	60828	213	1.00	
1 - 19 / day	14196	62	1.20	0.91 - 1.60
20 - 29 / day	19865	125	1.70	1.37 - 2.13
30+ / day	11288	68	1.64	1.25 - 2.15
Ex-smoker	73136	358	1.04	0.88 - 1.23
Pipe/Cigar only	1179	6	1.21	0.54 - 2.72

† Test of heterogeneity: P = 0.0001
Test for trend among current smokers: P < 0.0706

Table 29: *Cancer mortality by smoking category, adjusted for age and calendar period*

Smoking category	Person-years	Deaths	RMR†	95% C.I.
Never	71896	77	1.00	
1 - 19 / day	16678	35	1.88	1.26 - 2.81
20 - 29 / day	23046	69	2.63	1.90 - 3.65
30+ / day	13001	43	2.95	2.03 - 4.29
Ex-smoker	84885	118	0.90	0.67 - 1.20
Pipe/cigar only	1359	3	16.2	*

† Test of heterogeneity: P < 0.0001
Test for trend among current smokers: P < 0.039

Tables 30 and 31 show the relationship between smoking and lung cancer. For this outcome, the relationship to smoking is very strong – a 36-fold increase in risk in those smoking up to 19 cigarettes per day compared with the risk in those who have never smoked; a 62-fold increase in risk for those who smoke 21-30 cigarettes per day, and an 85-fold increase in risk for those who smoke more than 30 cigarettes per day. Even those who report having quit smoking have a 15-fold increase in risk. Figure 11, based on Table 30, shows in graphic form the sharp elevation in risk of lung cancer with increasing tobacco use.

The gradient of increasing risk of lung cancer with increasing tobacco use is much steeper than in most comparable studies. The reason is that in the present analysis only one lifelong non-smoker has developed lung cancer. Although the numbers of non-smokers with lung cancer are low in all such studies, a number as low as one is most unusual. However there is no reason to doubt this statistic. One of the great strengths of *Health Watch* is that the smoking histories have been collected prospectively. In most epidemiological studies smoking histories are collected retrospectively, giving lung cancer victims the opportunity to deny previous tobacco use.

This analysis reaffirms that lung cancer in people who have never been active smokers is a rare disease.

It should be emphasised that the comparisons in Tables 30 and 31 showing excess risk are comparisons made *within* the cohort. The *Health Watch* cohort as a whole has a significantly low rate of lung cancer incidence and lung cancer mortality compared with the general male population (Tables 10 and 11). The low lung cancer rate may appear unexpected given the fact that the standardised prevalence of smoking in the cohort is close to that of the Australian male population. The explanation may lie in the differences in smoking habits of the smokers. The comparison of smoking habits between *Health Watch* subjects and the Australian male population shown in Figure 6 relates only to prevalence (ie whether the person smokes or not). However lung cancer risk is exquisitely sensitive to factors such as number of cigarettes smoked, age at starting, age at quitting and tar content. Such factors could not be compared for the purposes of the analysis shown in Figure 6, but such differences (eg *Health Watch* smokers smoking fewer cigarettes per day than smokers in the general population) could easily account for the low lung cancer incidence in the *Health Watch* cohort.

Table 30: *Lung cancer incidence by smoking category, adjusted for age*

Smoking category	Person-years	Cancers	RIR†	95% C.I.
Never	60828	1	1.00	
1 - 19 / day	14196	9	36.76	4.66 - 290.16
20 - 29 / day	19865	22	62.40	8.41 - 463.11
30+ / day	11288	17	85.37	11.35 - 641.89
Ex-smoker	73136	27	15.79	2.14 - 116.28
Pipe/cigar only	1179	0	*	*

† Test of heterogeneity: P < 0.0001
Test for trend among current smokers: P < 0.0368

Table 31: *Lung cancer mortality by smoking category, adjusted for age*

Smoking category	Person-years	Deaths	RMR†	95% C.I.
Never	71896	1	1.00	
1 - 19 / day	16678	11	45.47	5.87 - 352.20
20 - 29 / day	23046	22	65.23	8.79 - 484.22
30+ / day	13001	21	113.10	15.20 - 841.77
Ex-smoker	84885	21	12.10	1.63 - 89.97
Pipe/cigar only	1359	0	*	*

† Test of heterogeneity: P < 0.0001
Test for trend among current smokers: P < 0.0103

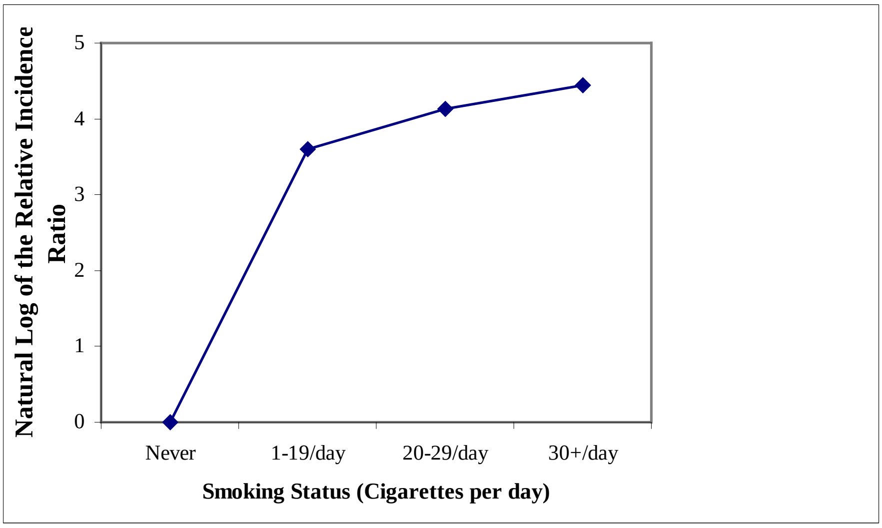

Figure 11: *Relative risk of lung cancer for different smoking categories compared to a baseline of non-smoker. (Note: the relative incidence rate is plotted on a logarithmic scale. The increased risk from smoking is so great that its effect could not be readily plotted on a linear scale.)*

3.5.4. Smoking and Ischaemic Heart Disease

Many studies have shown that smoking is a major risk factor for ischaemic heart disease (often called coronary artery disease) and this is confirmed in the *Health Watch* cohort. Table 32 shows that smoking dramatically affects the chance of dying from heart attack in the *Health Watch* male cohort. It is reasonable to assume that smoking similarly increases the risk of suffering a heart attack, even if death is not the outcome.

Table 32: *Ischaemic heart disease mortality by smoking category, adjusted for age and calendar period*

Smoking category	Person-years	Deaths	RMR†	95% C.I.
Never	71896	40	1.00	
1 - 19 / day	16678	21	2.17	1.28 - 3.68
20 - 29 / day	23046	39	2.84	1.83 - 4.42
30+ / day	13001	33	4.32	2.72 - 6.86
Ex-smoker	84885	92	1.32	0.91 - 1.91
Pipe/cigar only	1359	3	3.07	*

† Test of heterogeneity: P < 0.0001
Test for trend among current smokers: P < 0.0171

3.5.5. Deaths Attributable to Smoking

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 a crude figure is felt to be worth publishing (Figure 12). The effect of smoking in *Health Watch* is demonstrated in the results for cancer and ischaemic heart disease, being specific causes of death which can be analysed for smoking. In addition, there is no reason to suppose that other smoking-related diseases are not also happening in the cohort, just as they are in the Australian population as a whole.

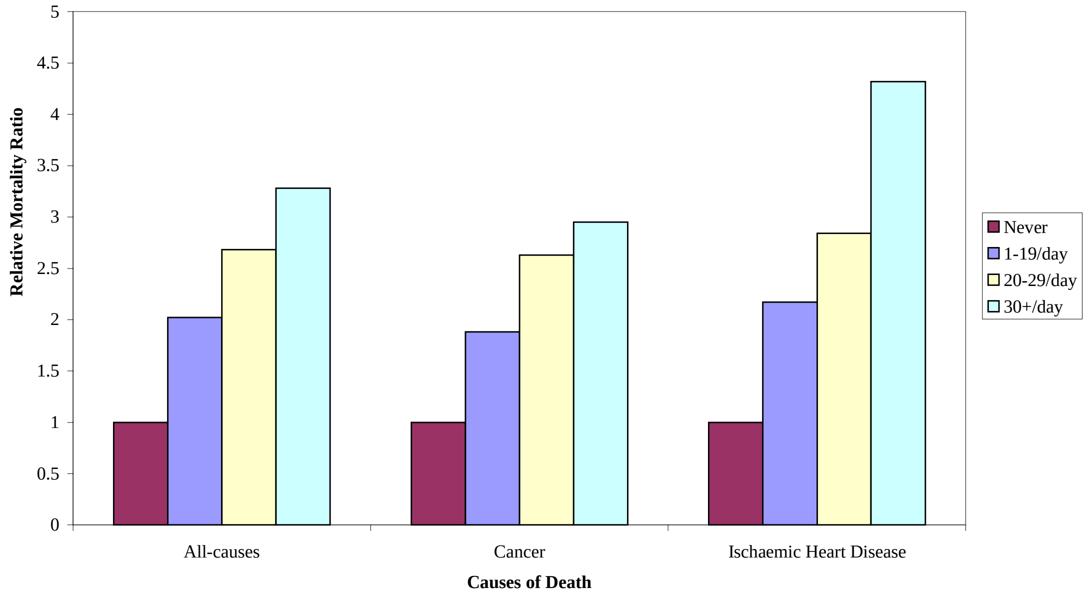

Figure 12: *Relative risk of dying from any cause, ischaemic heart disease or cancer for different smoking categories compared to a baseline of non-smoker. (The RMRs are adjusted for age.)*

The results indicate that smoking probably causes about half the ischaemic heart disease deaths and therefore about 110 men in the industry have died of heart attacks over the past 15 years due to smoking. Smoking accounts for virtually 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 one third of cancer deaths in the cohort, ie about 120 men. Combining all causes of death, it is estimated that smoking has played a part in about 320, or 37% of the 865 deaths that have occurred in the *Health Watch* cohort.•

3.5.6 Effects of Quitting

Men who give up smoking have better outcomes than those who continue 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 on mortality and cancer incidence can be seen in the *Health Watch* cohort.

• The estimates of excess deaths was computed by comparing the actual numbers of deaths with the number expected if the smokers had the same mortality rate as non-smokers. The expected numbers were derived by multiplying the rates for non-smokers by number of person-years of follow-up in all the smoking categories combined.

The relative mortality rate for deaths from all causes is not significantly higher in ex-smokers compared with those who have never smoked (RMR=0.97, 95% CI 0.81-1.17). For lung cancer mortality the risk in ex-smokers is considerably higher than in those who have never smoked, but much lower than in those who continue to smoke (RMR=12.1, 95% CI 2.1-89.97). These data are consistent with other studies which have shown that the risk of lung cancer declines as the time since quitting increases.[8,9] For all cancer deaths combined, the rate in ex-smokers is not significantly different form that of the general male population (RMR=0.90, 95% CI 0.67-1.20). In the case of death from ischaemic heart disease the RMR in ex-smokers is less than in current smokers. The RMR is in fact slightly greater than in those who have never smoked but the elevation is not statistically significant (RMR=1.32, 95% CI 0.91-1.91).

3.5.7. Alcohol Consumption

Health Watch information on consumption of alcohol has been reviewed with cross-checking of discrepancies between surveys. All-cause mortality is influenced by alcohol intake. Figure 13 shows the relative risk of dying (the relative mortality ratio RMR) for those who drink compared to those who are non-drinkers.

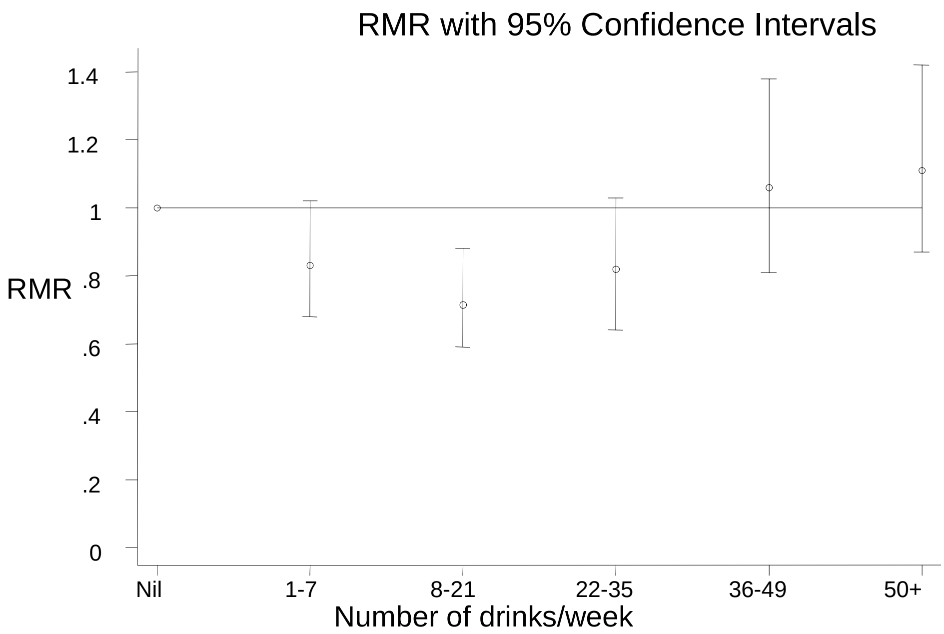

Figure 13: *Relative risk of dying (all-cause mortality) for different levels of alcohol consumption compared to the baseline of non-drinker. (The RMRs are adjusted for age and smoking.)*

Excessive drinking of over 35 drinks per week has a slightly adverse effect. A low to moderate consumption of alcohol (1-21 drinks per week) appears to be providing a positive or protective effect. This protective effect of low to moderate drinking produces a "U-shaped" or “J-shaped” curve in Figure 15 which has been reported in other studies.[10,11]

Table 33: *All-cause mortality by alcohol consumption, adjusted for age and smoking*

Number of drinks per week	Person-years	Deaths	RMR†	95% C.I.
Nil	36703	194	1.00	
1 - 7	50437	183	0.83	0.68 - 1.02
8 - 21	63112	191	0.72	0.59 - 0.88
22 - 35	27028	108	0.82	0.64 - 1.03
36 - 49	15992	78	1.06	0.81 - 1.38
50+	15294	97	1.11	0.87 - 1.42

† Test of heterogeneity: $P = 0.0013$
Test for quadratic (U-shaped) trend: $P < 0.0001$

4. SPECIFIC CANCERS

4.1 Lung cancer

Lung cancer incidence is significantly reduced in comparison with the general male population (SIR=0.66, 95% CI 0.52-0.83). Lung cancer mortality is also significantly reduced (SMR=0.65, 95% CI 0.51-0.81).

The occurrence of a number of cases of mesothelioma in the *Health Watch* cohort, and in some recently-published studies of oil refinery workers,[12,13] raises the possibility of an asbestos-related lung cancer risk also. However, the low lung cancer incidence indicates that the contribution of asbestos to this disease in the *Health Watch* cohort must be at most very small. Indeed the true fraction attributable to asbestos is probably nil. Lung cancer is a frequent consequence of asbestos exposure through malignant transformation of lung tissue affected by asbestosis. However no asbestos exposure sufficient to cause asbestosis has been reported in this industry. Although there is some advocacy of the view that asbestos can cause lung cancer at exposures too low to cause asbestosis, this question remains controversial.[14-16]

Nevertheless lung cancer is the largest individual cause of cancer mortality in the *Health Watch* cohort (76 deaths). This reflects the high incidence rate of this disease in the male population and the poor prognosis. Indeed the number of lung cancer cases is equal to the number of lung cancer deaths.

This outcome has been dealt with in more detail in relation to smoking. However it is clear that there is a strong case to maintain programs to induce employees to quit smoking. The poor prognosis shown by *Health Watch* data and other data are partly a reflection of the disappointing results of lung cancer screening programs to date, such as chest X-rays or sputum cytology.[17] Nevertheless consideration should be given to screening with high resolution computerised tomography (HRCT) scanning, which is capable of detecting extremely small lung tumours.

4.2 Mesothelioma

Of the 12 cancers of the pleura, 11 were mesotheliomas. There were no cases of peritoneal mesothelioma.

Mesothelioma is strongly related to asbestos exposure. Unlike lung cancer, most cases of mesothelioma are associated with some history of exposure to asbestos. Although the disease is most common in workers who have been heavily exposed, cases do occur in workers whose exposures have been too low to cause asbestosis. Moreover smoking does not appear to be a risk factor for mesothelioma.[18-19]

Because mesothelioma is nearly always associated with a history of occupational exposure to asbestos, every case should be regarded as significant in itself, irrespective of the SIR or SMR.

The occupational histories of the 11 cases of mesothelioma are not always sufficiently detailed to assess the probability of asbestos exposure. Nine cases occurred in refinery workers. Six of these nine subjects worked as fitters, welders or maintenance workers. Of these at least two cases had probably had significant asbestos exposure prior to entering the oil industry. The other three refinery workers had been in other occupations, at least one of whom and possibly all three, had had some asbestos exposure before entering the industry (in one case there was probable exposure in the oil industry in another country).

In the remaining two cases, asbestos exposure may have occurred prior to entering the industry but not since. Inspection of individual cases suggests that most of the asbestos exposures resulting in mesothelioma occurred prior to the 1970s.

4.3 Melanoma (ICD9: 172)

The incidence of melanoma is significantly raised in the *Health Watch* cohort (SIR=1.51, 95% CI 1.28-1.78). The excess of melanoma is sufficient to account for the entire excess incidence of cancer in the cohort: with melanoma excluded the SIR for all other cancers would be only 0.97.

Table 34 shows that the melanoma incidence is significantly elevated in all workplace types, except in the upstream sector: in the latter cases the estimates are based on small numbers.

Table 34: *Melanoma incidence by workplace type*

Workplace type	Person-years*	Observed	Expected	SIR	95% C.I.
Refinery	70964	58	38.08	1.52	1.16 - 1.97
Terminal	75280	65	41.04	1.58	1.22 - 2.02
Airport	6970	10	3.90	2.57	1.23 - 4.72
Onshore production	20179	5	8.99	0.56	0.18 - 1.30
Offshore production	7099	6	3.11	1.93	0.71 - 4.20
Total	180493	144	95.11	1.51	1.28 - 1.78

*Total person-years not equal to the sum of the displayed figures due to rounding

Tables 35 to 37 show the relative cancer incidence in successive periods of employment, according to duration of employment, and by time since first employment in the industry. There is no significant relationship between melanoma incidence and any of these time-associated variables.

Table 35: *Melanoma incidence by period of first employment, adjusted for age and calendar period of follow-up*

Period of first employment	Person-years	Cancers	RIR†	95% C.I.
Post - 1975	82033	40	1.00	
1965 - 74	61534	46	1.20	0.74 - 1.94
1955 - 64	25126	42	1.77	0.98 - 3.20
Pre - 1954	11800	16	1.20	0.56 - 2.55

† Test for trend: P = 0.3736

Table 36: *Melanoma incidence by duration of employment, adjusted for age and calendar period of follow-up*

Duration of employment	Person-years	Cancers	RIR†	95% C.I.
5 - 9 years	47300	25	1.00	
10 - 14 years	44814	26	0.85	0.48 - 1.50
15 - 19 years	33549	15	0.51	0.26 - 1.01
20 - 24 years	21835	26	1.06	0.56 - 2.01
≥ 25 years	32996	52	1.00	0.53 - 1.88

† Test for trend: P = 0.6055

Table 37: *Melanoma incidence by time since first employment, adjusted for age and calendar period of follow-up*

Time since first employment	Person-years	Cancers	RIR†	95% C.I.
5 - 9 years	38237	15	1.00	
10 - 14 years	42149	25	1.23	0.64 - 2.37
15 - 19 years	35302	19	0.86	0.41 - 1.78
20 - 24 years	24394	22	1.09	0.51 - 2.32
≥ 25 years	40410	63	1.19	0.56 - 2.51

† Test for trend: P = 0.7328

Tables 38 and 39 show the relative incidence of melanoma in ascending ranks of hydrocarbon rank score. These fail to show any association between melanoma and hydrocarbon exposure.

Table 38: *Melanoma incidence by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age and smoking*

Exposure Category	Person-years	Cancers	RIR†	95% C.I.
1	34615	36	1.00	
2	15504	9	0.85	0.40 - 1.78
3	1980	2	1.06	*
4	82044	54	0.73	0.48 - 1.12
5	6564	7	1.25	0.56 - 2.82
6	29099	26	1.00	0.60 - 1.66
7	10663	10	1.11	0.55 - 2.23

† Test for trend: p = 0.93

Table 39: *Melanoma incidence by total hydrocarbon exposure (based on total hydrocarbon ranking of longest job ever held), adjusted for age and smoking*

Exposure Category	Person-years	Cancers	RIR†	95% C.I.
1	46544	44	1.00	
2	16402	9	0.82	0.40 - 1.69
3	3058	2	0.76	*
4	75834	55	0.80	0.54 - 1.19
5	4829	4	0.91	0.33 - 2.25
6	25883	22	0.94	0.56 - 1.57
7	5241	6	1.19	0.51 - 2.80

† Test for trend: P = 0.8048

Thus the increased melanoma incidence is not site-specific; it shows no temporal relationship to employment and no association with hydrocarbon exposure. A causal association with any exposure in the workplace is thus unlikely. A plausible alternative explanation is an increase in the reporting rate in comparison with the general population. The occurrence of periodic medical examinations, as well as health promotion programs advising workers of the warning signs of skin cancer, would be expected to lead to a high reporting rate. If this leads to melanomas being reported at younger age groups than in the general population an elevated SIR could result.

Despite the excess melanoma incidence the mortality rate is low, although not significantly different from that of the general population (SMR = 0.90, 95% CI 0.50-1.48). This finding is consistent with early recognition as the cause of the raised incidence rate.

As discussed previously, there was also a significant excess of melanoma in females in the *Health Watch* cohort. It is highly unlikely that female workers in this industry could have incurred any occupational exposure likely to have caused melanoma, and increased detection is therefore the likely explanation of the raised SIR. That being so, early reporting is likely to have occurred in female workers in this industry also.

4.4 Bladder cancer

There is almost a 40% increase in the incidence of bladder cancer, and the increase is statistically significant (SIR=1.37, 95% CI 1.01-1.82). As shown in Table 40, the increased incidence occurs in each workplace type except onshore production, although the increase is not statistically significant in any.

Table 40: *Bladder cancer incidence by workplace type*

Workplace type	Person-years*	Observed	Expected	SIR	95% C.I.
Refinery	70964	22	14.48	1.52	0.95 - 2.30
Terminal	75280	18	15.48	1.16	0.69 - 1.84
Airport	6970	4	1.43	2.79	0.76 - 7.14
Onshore production	20179	2	2.28	0.88	*
Offshore production	7099	1	0.64	1.57	*
Total	180493	47	34.31	1.37	1.01 - 1.82

*Total person-years not equal to the sum of the displayed figures due to rounding

Tables 41 to 43 show the relative incidence of bladder cancer in successive periods of employment, according to duration of employment and time elapsed since first employment. Table 41 is suggestive of an increasing risk in those first employed after 1954, but this tendency is not statistically significant. Table 42 shows no association whatever between bladder cancer incidence and duration of employment. Table 43 suggests that the highest risk is in those first employed less than 10 years prior to diagnosis, but the trend is not statistically significant.

Table 41: *Bladder cancer incidence by period of first employment, adjusted for age and calendar period of follow-up*

Period of first employment	Person-years	Cancers	RIR†	95% C.I.
Post - 1975	82033	9	1.00	
1965 - 74	61534	13	0.83	0.33 - 2.12
1955 - 64	25126	16	0.99	0.36 - 2.78
Pre - 1954	11800	9	0.78	0.24 - 2.52

† Test for trend: P = 0.7638

Table 42: *Bladder cancer incidence by duration of employment, adjusted for age and calendar period of follow-up*

Duration of employment	Person-years	Cancers	RIR†	95% C.I.
5 - 9 years	47300	4	1.00	
10 - 14 years	44814	10	1.47	0.45 - 4.84
15 - 19 years	33549	6	0.74	0.20 - 2.81
20 - 24 years	21835	2	0.24	*
≥ 25 years	32996	25	1.01	0.30 - 3.43

† Test for trend: P = 0.6360

Table 43: *Bladder cancer incidence by time since first employment, adjusted for age and calendar period of follow-up*

Time since first employment	Person-years	Cancers	RIR†	95% C.I.
5 - 9 years	38237	4	1.00	
10 - 14 years	42149	5	0.67	0.17 - 2.58
15 - 19 years	35302	6	0.56	0.14 - 2.17
20 - 24 years	24394	6	0.45	0.11 - 1.88
≥ 25 years	40410	26	0.44	0.12 - 1.64

† Test for trend: P = 0.2398

Tables 44 and 45 show the relative incidence of bladder cancer in successive ranks of hydrocarbon rank score. When the analysis is based on the highest hydrocarbon rank score ever held, there is a clear and significant trend of increasing incidence with increased hydrocarbon exposure. In the analysis based on the total hydrocarbon ranking of the job held longest, there is a tendency for increasing relative incidence with increasing hydrocarbon exposure. The trend is of marginal statistical significance (p=0.09).

Table 44: *Bladder cancer incidence by total hydrocarbon exposure (based on highest hydrocarbon rank job ever held), adjusted for age and smoking*

Exposure Category	Person-years	Cancers	RIR†	95% C.I.
1	34615	6	1.00	
2	15504	1	0.80	*
3	1980	0	0.00	*
4	82044	24	2.14	0.87 - 5.25
5	6564	2	2.65	*
6	29099	9	2.22	0.78 - 6.29
7	10663	5	3.61	1.10 - 11.88

† Test for trend: P = 0.0125

Table 45: *Bladder cancer incidence by total hydrocarbon exposure (based on total hydrocarbon ranking of longest job ever held), adjusted for age and smoking*

Exposure Category	Person-years	Cancers	RIR†	95% C.I.
1	46544	8	1.00	
2	16402	1	0.66	*
3	3058	0	0.00	*
4	75834	26	2.08	0.94 - 4.61
5	4829	1	1.32	*
6	25883	8	1.84	0.68 - 4.92
7	5241	2	1.98	*

† Test for trend: P = 0.0958

Smoking is an important causal factor in bladder cancer, but is unlikely to be a confounding factor in this analysis. As discussed in the previous section, the smoking prevalence in the *Health Watch* cohort is comparable with that of the Australian male population. Moreover the low incidence of lung cancer suggests that smokers in the *Health Watch* cohort may on the whole have a lower level of tobacco use compared with the general population. These factors, together with the low mortality from non-malignant respiratory disease in this cohort suggest that the raised bladder cancer incidence is unlikely to be related to smoking.

The evidence of a dose-response relationship is inconclusive. When measuring a hypothetical occupational exposure by duration of employment, no trend is present, but the analysis based on hydrocarbon ranking is indicative of an association.

A possible contributing factor to the raised incidence could be an increased reporting rate, as is apparent in the case of melanoma. The absence of an elevated mortality rate for bladder cancer (SMR=0.98, 95% CI 0.43-1.94) would be consistent with early reporting with a high cure rate. Bladder cancer often responds well to treatment: cancer registry data show that bladder cancer cases outnumber bladder cancer deaths more than 2 to 1. Accordingly the increased bladder cancer incidence may be an artifact related to early reporting. This may be a further vindication of the practice of periodic medical surveillance of employees in the industry, especially if regular medical testing includes dipstick testing for the presence of haematuria.

Nevertheless, the possibility must be considered of increased bladder cancer incidence from exposure to an occupational chemical or chemicals. Consideration should be given to obtaining a detailed history from subjects with bladder cancer, particularly for agents suspected to cause bladder cancer such as polycyclic aromatic hydrocarbons and aromatic amines, and for surveillance of employees with potential exposure to these agents. Vigorous measures should also be taken to ensure that exposure to these agents does not occur.

4.5 Multiple myeloma

There is an excess incidence of multiple myeloma of marginal significance (SIR=1.68, 95% CI 0.94-2.78). As shown in Table 46, the excess is statistically significant in terminals. As shown in Table 47 there are no significant findings in relation to mortality from this disease.

Table 46: *Multiple myeloma incidence by workplace type*

Workplace type	Person-years*	Observed	Expected	SIR	95% C.I.
Refinery	70964	4	3.71	1.08	0.35 - 2.76
Terminal	75280	10	3.99	2.50	1.20 - 4.60
Airport	6970	0	0.38	0.00	*
Onshore production	20179	1	0.64	1.57	*
Offshore production	7099	0	0.19	0.00	*
	180493	15	8.91	1.68	0.95 - 2.78

*Total person-years not equal to the sum of the displayed figures due to rounding

Table 47: *Multiple myeloma mortality by workplace type*

Workplace type	Person-years*	Observed	Expected	SMR	95% C.I.
Refinery	82913	4	2.69	1.49	0.40 - 3.81
Terminal	86821	7	2.86	2.45	0.98 - 5.04
Airport	8063	0	0.27	0.00	*
Onshore production	24651	0	0.45	0.00	*
Offshore production	8415	0	0.13	0.00	*
	210865	11	6.41	1.72	0.86 - 3.07

*Total person-years not equal to the sum of the displayed figures due to rounding

The number of cases is too low to enable an analysis by time relationships or hydrocarbon exposures. Multiple myeloma and its relationship to benzene exposure is examined in the report of the case-control study by the consortium at Deakin and Monash Universities.

4.6 Leukaemias

As shown in Table 10, there is a 50% increase in the incidence of all leukaemia types combined, and the excess is statistically significant (SIR=1.50, 95%CI 1.02-2.15). There is an excess of all lymphoid leukaemias (acute and chronic) and all myeloid leukaemias (acute and chronic), but neither increase is statistically significant.

As shown in Table 48, the excess appears to be almost equally borne by refineries and terminals, although terminals do appear to have a slightly greater excess, this being statistically significant based on 16 cases with a SIR of 1.82, 95% CI 1.04-2.95).

Table 48: *Leukaemia incidence by workplace type*

Workplace type	Person-years*	Observed	Expected	SIR	95% C.I.
Refinery	70964	11	8.25	1.33	0.67 - 2.39
Terminal	75280	16	8.80	1.82	1.04 - 2.95
Airport	6970	1	0.82	1.22	*
Onshore production	20179	1	1.56	0.64	*
Offshore production	7099	1	0.48	2.09	*
	180493	30	19.92	1.50	1.02 - 2.15

*Total person-years not equal to the sum of the displayed figures due to rounding

Tables 49 to 51 show the relative incidence of all leukaemias combined, in successive periods of first employment, according to duration of employment, and according to lapse of time since first employment in the industry. As seen in Table 49, there is a marked trend towards increasing incidence the earlier the period of first employment. The incidence in those employed before 1954 is more than 4 times that in those employed since 1975, but estimates are based on small numbers. Table 50 shows that the incidence is higher in all categories of employment duration greater than 10 years compared with the category employed for less than 10 years, but there is no significant trend. As shown in Table 51 there is no significant trend in relation to lapse of time between first employment and diagnosis.

Table 49: *Leukaemia incidence by period of first employment, adjusted for age and calendar period of follow-up*

Period of first employment	Person-years	Cancers	RIR†	95% C.I.
Post - 1975	82033	7	1.00	
1965 - 74	61534	9	1.18	0.40 - 3.49
1955 - 64	25126	6	1.63	0.40 - 6.61
Pre - 1954	11800	8	4.30	0.94 - 19.64

† Test for trend: P = 0.0588

Table 50: *Leukaemia incidence by duration of employment, adjusted for age and calendar period of follow-up*

Duration of employment	Person-years	Cancers	RIR†	95% C.I.
5 - 9 years	47300	4	1.00	
10 - 14 years	44814	5	1.11	0.29 - 4.29
15 - 19 years	33549	6	1.51	0.38 - 5.98
20 - 24 years	21835	4	1.32	0.28 - 6.23
≥ 25 years	32996	11	1.86	0.43 - 8.11

† Test for trend: P = 0.3875

Table 51: *Leukaemia incidence by time since first employment, adjusted for age and calendar period of follow-up*

Time since first employment	Person-years	Cancers	RIR†	95% C.I.
5 - 9 years	38237	4	1.00	
10 - 14 years	42149	3	0.62	*
15 - 19 years	35302	5	1.10	0.26 - 4.67
20 - 24 years	24394	7	1.91	0.44 - 8.26
≥ 25 years	40410	11	1.29	0.27 - 6.16

† Test for trend: P = 0.4211

Tables 52 and 53 show the relative incidence of all leukaemias combined in ascending order of hydrocarbon exposure rank score. In the analysis based on the highest hydrocarbon rank job ever held there is a statistically significant trend of increasing incidence with increasing exposure. The finding is similar in the analysis based on the total hydrocarbon rank of the job held longest.

Table 52: *Leukaemia incidence by total hydrocarbon exposure (based on highest hydrocarbon rank job ever held), adjusted for age and smoking*

Exposure Category	Person-years	Cancers	RIR†	95% C.I.
1	34615	1	1.00	
2	15504	1	2.70	*
3	1980	0	0.00	*
4	82044	18	7.78	1.03 - 58.53
5	6564	1	6.43	*
6	29099	7	7.68	0.94 - 63.02
7	10663	2	6.47	*

† Test for trend: P = 0.0364

Table 53: *Leukaemia incidence by total hydrocarbon exposure (based on total hydrocarbon ranking of longest job ever held), adjusted for age and smoking*

Exposure Category	Person-years	Cancers	RIR†	95% C.I.
1	46544	2	1.00	
2	16402	1	1.58	*
3	3058	0		*
4	75834	19	5.43	1.26 - 23.35
5	4829	1	5.11	*
6	25883	7	5.30	1.09 - 25.70
7	5241	0		*

† Test for trend: P = 0.0393

Interpretation of these findings is made difficult by the conflicting results of dose-response analysis. Using hydrocarbon score as an index of exposure yields a positive dose-response, whereas using duration of employment as an index of cumulative exposure does not. There is epidemiological evidence of an association between benzene and leukaemia, in particular acute myeloid leukaemia, but the numbers of individual leukaemia types are too low for any causal association to be evaluated. The combining of acute and chronic lymphoid leukaemias, of acute and chronic myeloid leukaemias, and the combining of all leukaemias into a single “leukaemia” entity is somewhat arbitrary, since their differing occurrence and natural histories suggest that they are probably different diseases.

Leukaemia incidence in relation to benzene exposure is considered in detail in the report of the case-control study by the consortium at Deakin and Monash Universities.

There is no significant increase in mortality from these diseases (Table 11).

4.7 Non-Hodgkin's lymphoma

Non-Hodgkin's lymphoma incidence is not significantly different from that of the general male population. This is also true of all workplace types (Table 54).

Table 54: *Non-Hodgkin's lymphoma incidence by workplace type*

Workplace type	Person-years*	Observed	Expected	SIR	95% C.I.
Refinery	70964	13	13.92	0.93	0.50 - 1.60
Terminal	75280	16	14.97	1.07	0.61 - 1.74
Airport	6970	2	1.42	1.41	*
Onshore production	20179	3	3.04	0.99	*
Offshore production	7099	0	1.01	0.00	*
	180493	34	34.36	0.99	0.69 - 1.38

*Total person-years not equal to the sum of the displayed figures due to rounding

There was no significant finding in mortality rates for non-Hodgkin's lymphoma (Table 55)

Table 55: *Non-Hodgkin's lymphoma mortality by workplace type*

Workplace type	Person-years*	Observed	Expected	SMR	95% C.I.
Refinery	82913	8	7.03	1.14	0.49 - 2.24
Terminal	86821	5	7.48	0.67	0.22 - 1.56
Airport	8063	0	0.71	0.00	*
Onshore production	24651	0	1.43	0.00	*.
Offshore production	8415	0	0.46	0.00	*.
Total	210865	13	17.11	0.76	0.40 - 1.30

*Total person-years not equal to the sum of the displayed figures due to rounding

Summary box

***Comment on specific cancers
from the Cohort Analyses***

11 mesotheliomas have occurred in the cohort, mainly in refinery maintenance workers and operators. It is likely that several of these cancers are related to asbestos exposure in refineries, mostly before the 1970s, although some are likely to have resulted from asbestos exposure occurring prior to entering the oil industry. However, asbestos exposures do not appear to have been sufficient to cause any appreciable effect on the incidence of lung cancer, which shows a statistically significant reduction in incidence, despite a smoking prevalence in the Health watch cohort similar to that of the Australian male population.

There is an increased incidence of melanoma, which is likely to have resulted from increased rates of reporting rather than from any causal exposure in the oil industry. The mortality rate from melanoma is not significantly different from that of the Australian male population.

There is a significantly increased incidence of bladder cancer. The possibility of an occupational cause cannot be excluded.

There is an excess incidence of multiple myeloma of marginal statistical significance.

There is a statistically significant increase in the incidence of all leukaemias combined. Time-related analyses do not suggest a causal association with employment in the industry, but there is an increasing risk with increasing exposure to total hydrocarbons, using hydrocarbon rank score as an index of exposure.

It is likely that any true increase in risk of these diseases in the Health Watch cohort is confined to workers with particular occupational histories or exposures, and to specific diseases, eg acute myeloid leukaemia. Analyses based on the entire Health Watch cohort will tend to dilute such an effect, and the exploration of any association with benzene exposure is more validly pursued through the concurrent case-control study, which is the subject of a separate report.

5. HEALTH OUTCOMES IN SPECIFIC JOBS

The ability to assess risk in particular jobs as defined by their AIP Jobcode, is recognised to be a most useful method of assessing risk in the industry, because as groupings of jobs by workplace type eg all refinery workers, includes many jobs having very different exposures. However, analysing by AIP Jobcode is limited by the numbers of employees in any particular job. This number, with the multiplier arising from the length of time *Health Watch* has been in operation, produces person-years of observation for analysis. When person-years reach a sufficient size, analysis of risk for the employees holding that job can be done.

The AIP Jobcodes analysed in this report are “Drivers” (NB295x), “Refinery operators” (Bx, HX, Px, Rx), “Terminal operatives” (IB, NA, Bx, Px, RF, HX) and “Maintenance (refinery or terminal based)” (IX, Cx, Dx, Ex, Fx, GX, MX, LA, Rx), and shift workers. Each person’s full job history since 1980 was checked and the categorisation is according to whether the person has ever held the particular job classification. Those who have held more than one category appear in both categories in the analysis.

Analysis has been done for some major health outcomes including all cause mortality, ischaemic heart disease, cancer, and accidents and violence mortality in addition to cancer incidence. For many other health outcomes, numbers are very low and unreliable.

5.1. All-cause mortality

As shown in Table 56, there is no significant variation in all-cause mortality between any of the occupational categories.

Table 56: *All-cause mortality by AIP Jobcode*

JOB	Person-years	Observed	Expected	SMR	95% C.I.
DRIVER	29889	120	173.84	0.69	0.57 - 0.83
REFINERY	72656	250	370.58	0.67	0.59 - 0.76
MAINTENANCE	36307	120	173.31	0.69	0.57 - 0.83
SHIFTWORK	102291	361	551.68	0.65	0.59 - 0.73

5.2 Cancer incidence and mortality

As shown in Table 57, there is a statistically significant increase in cancer incidence in refinery operators. Specific cancers in excess in refinery workers are melanoma (SIR 1.54, 95% CI 1.14-2.05), and bladder cancer (SIR 2.34, 95% CI 1.48-3.51). The significance of the findings for these cancers is discussed in Section 4 of this report. Cancer mortality is significantly reduced in drivers (Table 58).

Table 57: *Cancer incidence by AIP Jobcode*

JOB	Person-years	Observed	Expected	SMR	95% C.I.
DRIVER	25850	130	113.13	1.15	0.96 - 1.36
REFINERY	61946	279	238.01	1.17	1.04 - 1.32
MAINTENANCE	30694	100	108.12	0.92	0.75 - 1.12
SHIFTWORK	87551	390	354.20	1.10	0.99 - 1.22

Table 58: *Cancer mortality by AIP Jobcode*

JOB	Person-years	Observed	Expected	SMR	95% C.I.
DRIVER	29889	43	59.56	0.72	0.52 - 0.97
REFINERY	72656	114	123.61	0.92	0.76 - 1.10
MAINTENANCE	36307	53	55.90	0.95	0.71 - 1.24
SHIFTWORK	102291	152	185.43	0.82	0.69 - 0.96

5.3 Ischaemic heart disease mortality

As shown in Table 59 there is no significant variation in mortality from ischaemic heart disease in any of the occupational categories. The absence of excess mortality in shift workers from this disorder is notable, since some epidemiological studies have suggested that shift work is a risk factor for heart disease.[20]

Table 59: *IHD mortality by AIP Jobcode*

JOB	Person-years	Observed	Expected	SMR	95% C.I.
DRIVER	29889	28	44.19	0.63	0.42 - 0.92
REFINERY	72656	52	91.02	0.57	0.43 - 0.75
MAINTENANCE	36307	30	41.46	0.72	0.49 - 1.03
SHIFTWORK	102291	89	137.46	0.65	0.52 - 0.80

5.4 Mortality from accidents and violence

As shown in Table 60 there is no significant variation in mortality from accidents and violence in any of the occupational categories.

Table 60: *Accident/violence mortality by AIP Jobcode*

JOB	Person-years	Observed	Expected	SMR	95% C.I.
DRIVER	29889	13	18.69	0.70	0.37 - 1.19
REFINERY	72656	33	46.19	0.71	0.49 - 1.00
MAINTENANCE	36307	14	24.09	0.58	0.32 - 0.98
SHIFTWORK	102291	46	64.89	0.70	0.52 - 0.95

Summary box

Comment on health outcomes in selected occupations

Drivers show statistically significant reductions in all-cause mortality, cancer mortality and mortality from ischaemic heart disease. Refinery workers show a significantly reduced all-cause mortality and mortality from heart disease but a significant increase in cancer incidence, due to excesses in melanoma and bladder cancer. Maintenance workers and shiftworkers show significant reductions in all-cause mortality and mortality from accidents/violence. Shift workers also show significant reductions in mortality from cancer and heart disease.

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