



Australian
National
University



PFAS Health Study

Overall summary

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Introduction

The Per- and Polyfluorinated Alkyl Substances (PFAS) Health Study investigated potential health effects of PFAS in three Australian communities with known environmental contamination (PFAS Management Areas): Katherine in the Northern Territory (NT), Oakey in Queensland (Qld) and Williamstown in New South Wales (NSW). These three sites were chosen because of the extent of PFAS contamination arising from historical use of aqueous film forming foams on Defence bases, along with well-understood exposure pathways. The Australian Government Department of Health commissioned the Australian National University (ANU) to conduct the PFAS Health Study between 2016 and 2021.

The PFAS Health Study started with a systematic review of the available scientific and health literature to identify potential health effects related to exposure to PFAS chemicals. Of the 148 health outcomes investigated, the review found sufficient evidence of an association between two PFAS chemicals—perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA)—and elevated blood cholesterol. The systematic review also found limited evidence of an association between exposure to PFAS chemicals and impacts on kidney health (high blood uric acid concentration, impaired glomerular filtration rate, chronic kidney disease), two specific cancers (kidney cancer and testicular cancer) and impacts on responses to specific vaccines (diphtheria and rubella).

The PFAS Health Study was conducted in four parts: (1) focus group discussions; (2) blood testing of PFAS concentrations in serum and biochemical markers of health; (3) a survey of PFAS exposure history and self-reported health status; and (4) data linkages to examine perinatal outcomes, childhood development, and cancer and cause-specific mortality outcomes. The blood testing, survey and data linkage elements involved people from PFAS Management Areas as well as, for comparison, people who had lived in similar areas in Australia that were not known to have environmental PFAS contamination. The focus group discussions, blood testing, and survey involved groups of individuals who agreed to participate, whereas the data linkage study used data records available for the PFAS Management Areas.

Overall, there was clear evidence of elevated blood serum concentrations of PFAS in residents and workers in the three PFAS-affected communities, and of increased psychological distress in the three exposed communities. The evidence for other adverse health outcomes was generally limited. For the majority of the health outcomes we studied, our findings were consistent with previous studies that have not conclusively identified causative links between PFAS and health outcomes. We did identify an association between higher PFAS blood levels and elevated serum cholesterol concentrations, which was consistent with evidence in the systematic review.

The findings of the PFAS Health Study are presented in four separate reports:

- *Component one: Oakey, Williamstown and Katherine Focus Groups Study*
- *Component two: Blood serum study of PFAS exposure, related risk factors and biochemical markers of health*
- *Component three: Cross-sectional survey of self-reported physical and mental health outcomes and associations with blood serum PFAS*
- *Component four: Data linkage study of health outcomes associated with living in PFAS exposure areas*

In this summary, we outline the key findings and overall conclusions from the PFAS Health Study. Further detail on how these studies were conducted can be found at: <https://rsph.anu.edu.au/research/projects/pfas-health-study>.

Main findings

Component one: Oakey, Williamstown and Katherine Focus Groups Study

The PFAS Health Study team conducted a series of focus group discussions in Katherine, Oakey and Williamstown in 2018. The Study aimed to understand participants' views and experiences of PFAS contamination in their local area, focusing on their health concerns. In total, 180 participants contributed to the Study, including 69 participants from Aboriginal communities in Katherine. Participants were concerned about the potential health risks from exposure to PFAS, particularly for their families and children. Participants were worried about cancers and aggravation of existing health conditions. Many participants discussed the psychological stress and anxiety they experienced as a result of living in an area with PFAS contamination, along with the associated uncertainty about health and financial implications. Many referred to feeling “trapped” or “stuck”. Participants indicated that they would like greater transparency and support in their interactions with government representatives. The focus group discussions contributed to the development of a questionnaire for the Cross-sectional Survey, including questions on psychological stress and social support. The Focus Group Study captured the changing experiences and emotions of those living and working in these towns. The report for this Study was published in March 2019.

Component two: Blood serum study of PFAS exposure, related risk factors and biochemical markers of health

The Blood Serum Study examined whether 2,587 people living or working in Katherine, Oakey and Williamstown had higher blood concentrations of PFAS compared to 702 people living in three comparison communities without known environmental contamination. The comparison communities—Alice Springs, NT, Dalby, Qld, and Kiama and Shellharbour, NSW—were chosen because they had similar profiles to the exposed communities in terms of socioeconomic status, remoteness and the proportion of residents who identified as an Aboriginal and/or Torres Strait Islander person. We measured the levels of nine different types of PFAS in blood serum along with biochemical markers of health. The chemicals PFOS, perfluorohexane sulfonic acid (PFHxS) and PFOA were detected in more than 80% of blood samples in each community and only these were included in further analyses in this study. PFOS and PFHxS were the main active ingredients of the firefighting foams that contaminated the environment of the exposed communities.

Geometric mean (a type of average) blood serum PFAS concentrations were higher in residents of PFAS Management Areas than in residents of comparison communities, except for PFOA where concentrations were similar. In the three PFAS Management Areas, the geometric mean concentration of PFOS in blood samples ranged from 4.9 to 6.6 nanograms per millilitre (ng/mL), while for PFHxS the mean values ranged from 2.9 to 3.7 ng/mL, and for PFOA they ranged from 1.3 to 1.8 ng/mL. Across the comparison communities, the geometric means of serum PFAS concentrations ranged from 2.5 to 3.3 ng/mL for PFOS, from 0.7 to 1.2 ng/mL for PFHxS and from 1.2 to 1.4 ng/mL for PFOA. Between 48% and 55% of participants from PFAS Management Areas had elevated blood concentrations of PFHxS, and between 29% and 42% of participants had elevated PFOS concentrations. Consuming bore water or certain locally grown foods at least weekly, longer residence in an exposed community and occupational exposure to firefighting foams were associated with elevated blood concentrations of PFOS and PFHxS. Study participants

from PFAS Management Areas reported reducing their use of bore water and local produce once they were alerted to the contamination.

Overall, there was little association between PFAS and biochemical markers of disease risk, however, higher PFAS blood serum concentrations were associated with a higher prevalence of elevated total cholesterol in participants from Williamstown, and higher prevalence of elevated uric acid (a marker of kidney function) in participants from Williamstown and Katherine. However, it is important to note that differences were small and unlikely to be relevant to health.

Recruitment of participants in this blood serum study was through self-selection meaning that the blood concentrations may not be representative of everyone who lived or worked in the PFAS Management Areas.

Component three: Cross-sectional survey of self-reported physical and mental health outcomes and associations with blood serum PFAS

The Cross-sectional Survey investigated the exposure history, physical health, and mental health of 917 people living or working in the three PFAS Management Areas and a total of 801 people living in the three comparison communities. Participants reported whether they had ever been diagnosed with any of 32 health conditions, fertility problems, whether they had started menopause, mental health symptoms, and their concerns about living or working in PFAS Management Areas. We compared the prevalence of self-reported health outcomes, including those relating to psychological distress, between exposed and comparison communities. We quantified the association between self-reported health outcomes and blood serum concentrations of PFOS, PFOA, and PFHxS.

Survey participants from PFAS Management Areas reported a higher prevalence of a range of health conditions compared to participants from comparison communities; however, results should be interpreted with caution because the survey represents only a cross-section of people at a point in time who chose to participate in the survey. Additionally, participants reported on their health status and we did not validate disease occurrence using medical records. PFAS levels were measured after disease had already occurred.

Compared to participants from Alice Springs, a higher proportion of Katherine participants reported cancer and liver disease, while Williamstown participants reported a higher prevalence of rheumatoid arthritis, hypercholesterolaemia (high blood cholesterol), type II diabetes, and fertility problems than Kiama and Shellharbour participants. We were unable to make reliable comparisons regarding self-reported health outcomes between participants from Oakey and Dalby due to the smaller number of participants. Importantly, PFAS concentrations in blood serum were not associated with higher prevalence of most self-reported health conditions. In some exposed communities, we observed higher prevalence of self-reported gout, hypercholesterolaemia, and hypothyroidism (lowered thyroid activity) with higher blood serum concentrations of PFOA, which was not elevated in the blood serum of people in exposed communities compared to the comparison communities.

Participants from PFAS Management Areas reported higher levels of psychological distress than those of comparison communities. Psychological distress was highest among participants who were occupationally exposed to firefighting foam, among participants who used bore water on their properties, and among participants who were concerned about their health. Overall, one in three participants in PFAS Management Areas reported being 'very' or 'extremely' concerned about their health and one in five reported being 'very' or 'extremely' concerned about their mental health.

Component four: Data linkage study of health outcomes associated with living in PFAS exposure areas

The Data Linkage Study used retrospective routinely-collected data to investigate health outcomes over several decades among people who had ever lived in a PFAS Management Area (exposed populations). We examined whether rates of adverse health outcomes were higher among the exposed populations than among people who had lived in comparison areas in Australia that were not known to have environmental PFAS contamination. The comparison areas were similar in terms of socio-demographic characteristics to the PFAS Management Areas. They were not the same comparison communities used in the Blood Serum Study and Cross-sectional Survey.

We conducted three separate studies investigating a total of 48 health outcomes: Study 1 investigated maternal and infant (perinatal) health outcomes; Study 2 examined childhood development; and Study 3 investigated cancer and death from specific causes. We investigated three control outcomes nominated *a priori* that were not known or thought to be associated with PFAS exposure. Control outcomes provided one way of assessing the robustness of the findings – we expected that rates of control outcomes would be similar across the exposed and comparison populations.

We selected participants based on their place of residence as recorded in the State/Territory Perinatal Data Collections of NT, Qld or NSW at the time of giving birth (Study 1), or the national Medicare Enrolment File (Study 2 and Study 3). The exposed populations included everyone who had a recorded address in any of the three PFAS Management Areas. In Study 1, we included data on 29,099 pregnancies in exposed and comparison areas for the years ranging from 1986–2018. For Study 2, we included developmental outcome data on 14,925 children for the years 2009–2018. In Study 3, we included cancer and death data on 599,393 people for the years 1980–2019, representing approximately 8.5 million person-years of data. We estimated the relative rates of each outcome (relative risks for perinatal and childhood developmental outcomes, and standardised incidence ratios for cancer and cause-specific mortality outcomes), accounting for potential confounders (other factors, such as age, that could account for differences in the rates of observed outcomes) wherever possible.

For most health outcomes examined, we did not conclude that rates were higher in the PFAS Management Areas relative to the comparison areas. For several adverse health outcomes, we estimated small to modest elevations in rates of individual outcomes in one of the exposure areas: in Katherine, prostate cancer; in Oakey, stillbirth, developmental vulnerability in two domains of the Australian Early Development Census (physical health and wellbeing, and communication skills and general knowledge), and laryngeal cancer; and in Williamtown, postpartum haemorrhage (excessive bleeding during childbirth), pregnancy-induced hypertension (high blood pressure), kidney cancer, and lung cancer. Death rates from coronary heart disease were elevated in both Oakey and Williamtown compared to their respective comparison areas. We also observed elevated rates of the selected control outcomes compared to comparison areas: in Oakey, death from intentional self-harm and death from other external causes; and in Williamtown, death from intentional self-harm.

These findings should be interpreted carefully considering the studies' strengths and weaknesses. We did not use direct measurements of PFAS exposure in blood but relied on residential history. Results could be biased by differences between the exposed and comparison populations that we could not account for; in particular, we did not have complete information for certain risk factors, such as smoking, and we were unable to fully control for socioeconomic factors. Additionally, some findings may be purely due to chance, as we studied many outcomes. There were only two health outcomes where rates were elevated in more than one PFAS Management Area: coronary heart disease mortality and the control outcome of death from intentional self-harm. There is, therefore,

very limited support in these studies for effects of living in PFAS Management Areas on the health outcomes studied.

Overall conclusions

The results of the PFAS Health Study provide insights into the potential health effects of PFAS contamination on three communities in Katherine, Oakey and Williamtown. We draw several key conclusions:

- There were adverse psychological impacts associated with living in PFAS-affected towns, as demonstrated by surveys of, and focus groups with, people participating in the Study.
- Blood serum concentrations of PFOS and PFHxS in residents and workers of PFAS Management Areas were higher than in residents of comparison communities, which was not observed for PFOA.
- The main risk factors for elevated blood concentrations of these chemicals were length of residence in an exposed community, at least weekly consumption of bore water or certain locally grown foods, and occupational exposure to firefighting foams.
- Higher concentration of PFAS in blood serum was associated with elevated blood cholesterol levels in participants from Williamtown and uric acid levels (a marker of kidney function) in participants from Williamtown and Katherine. However, these differences were small and unlikely to be important to health.
- In the cross-sectional survey, people who lived or worked in PFAS Management Areas were more likely to self-report various health outcomes than participants from comparison communities. However, participation in the survey was voluntary, so survey findings may not accurately reflect the situation in the whole community.
- The prevalence of self-reported diseases was largely not associated with higher PFAS concentrations in blood serum, nor were associations consistently observed across the three exposed communities.
- An extensive data linkage study provided limited support for adverse health effects from living in PFAS Management Areas. While there were higher rates of some adverse outcomes in individual areas, they were rarely present in more than one area and we could not reasonably rule out that these were due to chance or caused by factors other than exposure to PFAS.
- Across three of the component studies, we observed associations between blood serum concentrations of PFAS and elevated total cholesterol in blood serum and self-reported history of hypercholesterolaemia, and between living in a PFAS Management Area and increased deaths due to heart disease.

The combined information from these four component studies informs our understanding of the effects of PFAS on health in these communities. Overall, there was clear evidence of elevated blood serum concentrations of PFAS in residents and workers in the PFAS-affected communities compared to the comparison communities. There was clear evidence of increased psychological distress in the three exposed communities. There was an association between higher PFAS levels and elevated cholesterol levels that was consistent with the systematic review. The evidence for other adverse health outcomes was generally limited. For the majority of the health outcomes we studied, our findings were consistent with previous studies that have not conclusively identified causative links between PFAS and adverse health outcomes. Study findings emphasise the importance of support for communities where environmental contamination has occurred. The PFAS Health Study may serve as a guide for future research efforts on PFAS and health.