Government of Western Australia
Department of Health

Position statement: Service stations and sensitive land uses

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1 Purpose

This document provides the Department of Health position on adequate separation distances between service stations and sensitive land-uses, such as residences, child-care centres, and schools. This document is predominantly for local governments to support them in their decision-making for development applications involving service stations.

2 Background

The department is regularly requested to provide public health advice on planning applications involving development of service stations in close proximity to an existing sensitive land-use, such as a residence or child-care centre, or for the development of a sensitive land-use that may be in close proximity to an existing service station. The department refers to the *Environmental Protection Authority (EPA) Guidance for the assessment of environmental factors: Separation distances between industrial and sensitive land uses (EPA, 2005)* to provide guidance. This document has three categories for service stations: premises operating during normal hours (0700 – 1900), freeway service centres (24 hours), and all other 24-hour operations. Separation distances for these categories are 50m, 100m, and 200m, respectively. However, it does not include, or cite, the evidence that supports the published distances and being nearly 20 years old may not be reflective of current associated exposure circumstances.

The main concern for public health is from gaseous emissions, specifically benzene and other volatile organic compounds (VOCs). Other matters, such as noise, light and odour, need to be considered when assessing applications and are addressed by subject matter experts within the Department of Water and Environmental Regulation (DWER).

To inform this position, a review of scientific literature was conducted (Appendix A). The review considered; the contribution of emissions from service stations to the surrounding air quality; potential exposure of nearby residents to emissions from service stations; and epidemiological studies of health effects in people living in close proximity to service stations.

3 Position statement

The Department of Health continues to support the use of minimum separation distances of:

- 50 metres for service stations operating during normal business hours
- 100 metres for 24-hour service stations.

At this time there is insufficient evidence to support the 200m distance for non-Freeway 24-hour service stations.

The department recommends the above distances are maintained in the absence of evidence to justify a reduced distance (see below for site specific considerations below).

4 Literature review summary

4.1 Gaseous emissions from service stations

- Service stations can contribute significantly to concentrations of benzene and other VOCs in the air at and surrounding the station site. Concentrations vary greatly both in magnitude and distance from the service station and are dependent on factors such as:
  - the fuel throughput, fuel composition, and temperature of the fuel
  - use of recovery systems
  - meteorological conditions such as ambient temperature and humidity, and wind direction and speed
  - surrounding topography.

- Some international studies have found that concentrations of benzene and other VOCs remain above background up to 150m from the stations, although most studies do not find air quality impacts beyond 100m from the boundary of the stations.
- Both indoor benzene concentrations and personal exposure to benzene are increased with residential proximity to service stations, at least within 50m of the stations.
- There are no published local data on concentrations of benzene near service stations.

4.2 Health effects of petrol gaseous emissions

- There are a range of both acute and chronic health effects associated with benzene and other VOCs.
- Benzene is classified as a human carcinogen, specifically for leukaemia. There is no known safe level of exposure.
- The relationship between benzene and cancer in adults is well established. For children, there are fewer data but studies have suggested links to childhood leukemia.
- Long-term exposure to other VOCs, such as toluene, ethylbenzene and xylene, emitted from petrol has been associated with adverse effects on the respiratory and central nervous systems, as well as producing kidney damage and cancer.

4.3 Health effects of living near a service station

- Nine studies have investigated residential proximity to petrol stations and cancer; most (n=6) have focussed on childhood cancers. These have consistently shown an increased risk of cancer, particularly leukaemia, in children living close to service stations.
- Exposure for all these studies was based on residential proximity to service stations, not quantifiable benzene or other VOC exposure concentrations. Although ‘close proximity’ varied between studies (from adjacent to within 100m), the most recent evidence suggests that risk is increased at least within 50m of service stations.

4.4 Conclusion

There is good evidence that service stations contribute to concentrations of benzene and other VOCs in the surrounding air and that there is an increased risk of cancer, particularly childhood leukaemia, for people living near service stations. Based on these data, and applying the precautionary principle, the recommended separation distances for service stations are at least 50m for those that operate during business hours (0700 – 1900) and 100m for all 24-hour stations.

5 Site specific considerations

The EPA Guidance states that the distance is boundary to boundary and where the separation distance is less than the generic distance, a scientific study based on site- and industry-specific information must be presented to demonstrate that a lesser distance will not result in unacceptable impacts. The department generally defines an unacceptable risk for a carcinogen as greater than a 1/1,000,000 excess lifetime risk of cancer, although 1/100,000 has also been used. Based on current evidence this means service stations should not contribute to benzene concentrations either 0.17ug/m^3 (for 1/1,000,000) or 1.7ug/m^3 (for 1/100,000) above background concentrations at a sensitive land-use. However, due to uncertainties in air dispersion modelling (see below) and the lack of robust air quality monitoring data, it is difficult to estimate the contribution of service stations to benzene concentrations at nearby sensitive land-uses.

Best practice planning is to separate sensitive receptors from sources of emissions and, until more data are available, the department recommends applying the separation distances in this position statement. However, the final decision to allow a service station, or other, development rests with the local government. The following factors can be considered when assessing proposals for service stations or sensitive land-uses that are within the recommended separation distances of each other.

1. Boundary to boundary separation distance allows for industry to use all of their land for their activities, including ones that emit contaminants of concern. For service stations it is unlikely the emission sources of concern (bowsers or storage tanks) will be placed on the boundary and, therefore, in some cases emission source to boundary can be accepted on the basis that the separation distance considers possible expansion or movement of facilities, or the impracticability of any such changes is stated.

2. Air dispersion modelling is often presented by proponents to support their proposal. However, air dispersion modelling has a number of areas of uncertainty that cannot be verified. Furthermore, commonly used steady-state plume models also have limitations in the near field below distances of around 100m, which is the typical resolution for service stations. Dispersion modelling, therefore, should not be used as a basis for reducing separation distances from sensitive receptors.

3. There are many examples in Perth of service stations that do not comply with the separation distance guidance and an assumption that there have been no health issues related to these. This is an invalid assumption as both acute and chronic health effects are non-specific and have many causes, and are, therefore, difficult to link directly to service station emissions. There are currently no data to support the assumption of no adverse health impacts from existing service stations built within the separation distances.

4. There are no national air quality standards for benzene and other VOCs in Australia. The National Environmental Protection Measure for air toxics, including benzene, toluene and xylene, remains a goal to “improve the information base regarding ambient air toxics with the Australian environment in order to facilitate the development of standards”. The air toxics NEPM includes a monitoring investigation level (MIL), which is ‘the concentration of an air toxic which if exceeded requires an appropriate form of further investigation and evaluation’. For benzene the MIL is 3 ppb (10 $\mu g/m^3$) as an annual average.

5. Vapour recovery technology (VRT) has significantly reduced VOC emissions from service stations. Stage 1 vapour recovery (VR1) controls emissions from underground storage tanks while the tanks are being filled from road tankers. Stage 2 vapour recovery (VR2) controls emissions from vehicle tanks during refuelling at petrol bowsers. Although none of the epidemiological studies explicitly state what VR systems are used, all of them were conducted after VRT was available and, in most cases, after VR1 was mandated. However, VR2 is less likely to have been introduced during the relevant study periods. In WA, VR1 is mandated; VR2 is not and if applied might be considered a mitigating feature in relation to any application for a reduced separation distance of 100m to 50m for 24 hour service stations.

6. Surrounding landforms and structures, and planned landscaping can be considered if defendable arguments can be made about their effectiveness.

Appendix A: Literature review

A1. Purpose

The purpose of this literature review is to present the available evidence underpinning the Department of Health position regarding the separation distance between service stations and sensitive land uses, such as homes, child-care centres and schools. The document also highlights where there is a lack of data, particularly important local data, that also informs the department's position. The focus of the position is the potential health impacts of gaseous emissions, particularly benzene and other volatile organic compounds (VOCs). This review considers the current (until 2024) national and international data on:

- emissions of benzene and other VOCs from service stations
- exposure of the community to benzene and other VOCs from service stations
- health risks associated with exposure to benzene and other VOCs, as well as proximity to service stations.

A2. The issue

The department provides advice on development applications involving service stations. Advice is based on the 2005 EPA separation distance guidance (*GS3: Guidance for the Assessment of Environmental Factors: Separation Distances between Industrial and Sensitive Land Uses. June 2005)* [1]. This document has three categories for service stations: premises operating during normal hours (0700 – 1900), freeway service centres (24 hours), and all other 24-hour operations. Separation distances for these categories are 50m, 100m, and 200m, respectively. Impacts of concern include gaseous, noise, odour and risk.

Noise and odour are regularly addressed in development applications. When gaseous emissions are addressed, developers have in the past, incorrectly, referred to the *Dangerous Goods (DG) Act*. The *DG Act* deals with acute hazards such as fire and explosion. However, from a public health point of view the concern is chronic exposure to petrol vapours. Petrol vapours contain a range of chemicals, including VOCs, such as BTEX and service stations are a source of these compounds in the air within and surrounding the site. Of particular concern is benzene, which has been classified by the International Agency for Research on Cancer (IARC) as a Group 1 (carcinogenic to humans) carcinogen [2]. Benzene is an established cause of acute myeloid leukaemia (AML) in adults and, although research is inconclusive, there are also positive associations between benzene and leukaemia in children [2].

Chronic exposure to other VOCs such as toluene, ethylbenzene and xylene also can lead to adverse health outcomes. Long-term exposure to xylene and toluene adversely affects the respiratory and central nervous systems, while ethylbenzene has been associated with kidney damage and cancer.

Current situation

The department continues to recommend that separation distances, as published in the EPA Guidance, are adhered to in the absence of a site-specific technical study. This is consistent with the EPA Guidance, Section 4.4.2, p10. For gaseous emissions any site-specific technical study should demonstrate that development within the default distances will not represent an unacceptable health risk.

To determine a health risk, it is necessary to have an estimate of exposure. In this situation that will require an understanding of the impact, if any, of the vapour emissions from service stations on the air quality at the sensitive land-use site. Air quality can be determined two ways;

monitoring and/or modelling. As far as the department is aware there are no available monitoring data in or around service stations in Western Australia that could be used to support site-specific studies. Furthermore, applications for service stations that do not comply with existing separation distance guidance rarely, if ever, include monitoring data. With regards to modelling, advice from the Department of Water and Environmental Regulation (DWER) is that due to uncertainties in model inputs, air dispersion models are not suitable to make precise judgements on separation distances. These limitations mean that the department cannot accept health risk assessments that rely on air dispersion modelling to estimate exposure.

The separation distance document was published in 2005 and, although the department is not aware of any changes in fuel composition or emission technology since that time, may be outdated. Furthermore, the reason(s), and supporting evidence, for the published distances are not provided. The following sections present a review of the current literature of VOC emissions from service stations, as well as studies of the health effects, particularly in children, associated with proximity to service stations. The evidence below is used to inform the department position on the siting of petrol stations relative to sensitive land-uses.

A3. Literature Review

A3.1 Gaseous emissions from service stations

Petrol is a highly volatile liquid with a complex mixture of aliphatic and aromatic hydrocarbons. These hydrocarbons can vaporise at low temperatures and, unless captured, the vapour is released into the atmosphere. Petrol vapours contain a large number of volatile organic compounds (VOCs) including benzene, toluene, ethylbenzene and xylene (BTEX compounds). These vapours can be released during the refilling of underground petrol storage tanks and the filling of vehicle fuel tanks. The displacement of petrol vapour during these operations is equal in volume to that of the fuel being transferred. Vapours can also be released from accidental spills and fugitive emissions through leaky pipes and fittings.

Vapour recovery systems have been designed to limit the emissions of VOCs during the refilling of storage tanks (Stage 1 vapour recovery – VR1) and refuelling from bowsers (Stage 2 vapour recovery – VR2). In most jurisdictions, including Western Australia, VR1 systems are mandated. Stage 2 VR regulations are less common and are not a requirement for petrol stations in WA.

The main factors that influence vapour emissions from a petrol station include:

- the number of bowsers and fuel throughput (how much petrol is pumped annually)
- type of petrol/fuel
- temperature of the petrol
- ambient temperature
- presence of recovery systems
- storage tank venting systems.

Other factors that are important for the dispersion of vapours into the nearby atmosphere include.

- meteorological conditions (temperature and wind)
- topography and surrounding buildings
- photochemical reactions in the atmosphere.

Concentrations of VOCs around the petrol station will also depend on other sources, such as traffic and industry, and background concentrations.

Internationally, a number of studies have investigated airborne BTEX concentrations in and around service stations. Concentrations are highest within service stations but can still be elevated some distance from the service. However, there is considerable variation in the reported findings. Below is a list of studies that measured, or modelled, VOC concentrations beyond the boundary of service stations.

1. In the UK, monitoring was conducted up to 50m from petrol stations. The contribution of the petrol stations to annual benzene concentrations at 50m varied from 0 and 4 μg/m^3 [3]. Small petrol station with pumps close to the boundary had a greater off-site influence than larger petrol stations with pumps at a greater distance from the boundary.
2. In Taegu, Korea, benzene concentrations were, on average, about 50% higher in the outdoor air of homes within 50m of the station compared to homes >100m (4.8 v 3.2 μg/ m^3) [4].
3. In Malta, BTEX concentrations were higher in the outdoor (1.13 v 0.72 μg/m^3, respectively) and indoor (0.86 v 0.72 μg/ m^3, respectively) air for buildings within 40m of service stations compared with those >40m from the stations [5].
4. In Oporto, Portugal, BTEX concentrations were higher in the outdoor air of homes within 80m of a petrol station compared with outdoor air of homes that were >300m from the station [6]. Benzene concentrations were 1.8 and 1.5 μg/ m^3, respectively, for homes within 80m and beyond 300m. In the more proximal group, there was no difference in outdoor or indoor airborne concentrations of benzene for homes within 40m of the service station and those between 40 and 80m.
5. Two studies used a mixture of modelling and monitoring to determine the distance of influence of the petrol station on ambient BTEX (i.e., the distance from the petrol station that ambient BTEX is still elevated due to emissions from the petrol station). Distances were.
   a. 75m in Murcia, Spain [7]
   b. 150m in Rio de Janiero, Brazil [8]
6. Health Canada [9] conducted a modelling only study using three scenarios based on annual petrol throughput (1 million L/yr, 4 mL/yr, and 10.6 mL/yr). In all scenarios the peak benzene concentration was 20m from the station boundary. For the 1 mL/yr scenario, benzene was at background concentrations by 50m from the boundary. However, background benzene concentrations were not achieved until 100m and 200m for the 4 mL/yr and 10.6 mL/yr scenarios, respectively. Peak (20m from boundary) modelled benzene concentrations for the 3 scenarios were 0.88, 3.5 and 9.2 μg/m^3, respectively.

Personal exposure of both children [10] and adults [11, 12] to BTEX compounds has also been demonstrated to be influenced by residential proximity to petrol stations.

There have been no published studies in Australia of ambient BTEX, or other VOCs, concentrations in the vicinity of petrol stations, although car refuelling at petrol stations has been reported as a significant contributor to personal benzene exposure for people in Perth and other Australian cities [13]. An air toxics, including VOCs, monitoring campaign was last conducted in Perth in 1997/1998 [14]. This study did not explore petrol stations as a potential source of VOCs in the Perth airshed.

Conclusion: Petrol stations contribute to ambient and indoor concentrations of VOCs in the near vicinity of the station. In some cases, emissions from petrol stations can influence BTEX up to 150 m from the station. Proximity to petrol stations is also an important contributor to personal exposure to BTEX compounds in both adults and children. There is great variation in the findings both in concentrations and distance of impact. **Studies have not always indicated the presence, or absence, of VRT**. Vapour recovery technology was developed about 50 years ago and, VR1 at least, introduced in the USA and most of Europe by the mid-1990s. Therefore, for most studies presented above VR1 technology is likely to have been present.

There are currently no recent WA, or Australian, monitoring data on benzene and other VOCs from service stations. Nor are there recent data on background concentrations of VOCs in Perth. Air dispersion models have a number of limitations and are not suitable to make precise judgements on separation distances. Therefore, it is currently not possible to estimate the contribution of service stations in WA to local air quality.

A3.2 Health effects of petrol vapours

Many VOCs in petrol vapours have acute and/or chronic health effects. Breathing small amounts of petrol vapour can lead to nose and throat irritation, headaches, dizziness, nausea, vomiting, confusion and breathing difficulties. Chronic exposure to high levels (e.g., intentional recreational inhalation) is associated with a range of neurological disorders. Less is known about chronic exposure to low concentrations to petrol vapours, but there is considerable concern about benzene, a known carcinogen.

Benzene

Benzene has been classified by the International Agency for Research on Cancer (IARC) as a Class 1 (known) human carcinogen, particularly for acute myeloid leukaemia (AML) in adults [2]. Studies have also suggested links to childhood leukemia (particularly AML) as well as acute lymphocytic leukemia (ALL), chronic lymphocytic leukemia (CLL), and other blood-related cancers (such as multiple myeloma and non-Hodgkin lymphoma) in adults.

Benzene is a non-threshold carcinogen. That means there is no threshold below which carcinogenic effects have not been observed. However, at low concentrations, such as those found in the general environment, the risk of disease is low. For example, the excess risk of leukaemia of a lifetime exposure to benzene in the air at concentrations of 1 $\mu g/m^3$ is about 6 in a million [15]. Background benzene concentrations in cities can range from <1 to 10 $\mu g/m^3$. Data from above show that benzene concentrations within 50m of service stations can range from ~1 to > 9 $\mu g/m^3$.

Most epidemiological studies of benzene are in occupational cohorts (occupational exposures). There are much less data from non-occupational studies. Non-occupational studies have predominantly focussed on childhood cancers and the most recent systematic review and meta-analysis of studies of outdoor air pollution reported a significant increased risk of leukaemia, particularly AML, in children from ambient benzene [16]. There was evidence of a linear dose-response relationship with no indication of a threshold level [16]. The risk seemed to be greater in pre-school children (<6 years of age) [16]. There is also evidence that maternal exposure to benzene in the outdoor air during pregnancy increases the risk of leukaemia in children [17].

Benzene has also been associated with adverse birth outcomes. In a 2012 systematic review Protano et al. [18] found that there was evidence for the association between an increase in preterm birth or a decrease in biparietal diameter growth with maternal exposure to benzene or early exposure to aromatic solvents. The relationships between benzene exposure during pregnancy and other parameters (i.e., birthweight, foetal weight, birth length, head circumference growth, foetal femur length, and abdominal circumference) were inconclusive [18]. Studies published since that time have mostly, but not always [19], reported significant associations between ambient benzene concentrations and pre-term birth [20, 21] but not birth defects [22, 23].

Other VOCs

Long-term exposure to xylene and toluene can adversely affect the respiratory and central nervous systems. This includes asthma or asthmatic symptoms such as dyspnea, cough, wheeze, and chest tightness, and breathing difficulties, and neurological symptoms such as headaches, dizziness, nausea, fatigue, agitation, and confusion. Long term exposure to ethylbenzene may produce kidney damage and cancer [24].

Conclusion: Benzene and other VOCs emitted from petrol vapours have known and established health effects, including cancer. There is no known safe threshold for benzene and low-level environmental exposures have been associated with these adverse outcomes. The risk is relatively low but at benzene concentrations reported around service stations can exceed an unacceptable risk of 1 extra cancer per 100,000. This is the risk for leukaemia based on the understanding of studies in adults. The risk may be higher for children. Furthermore, this is the risk for just one of a number of potential adverse health outcomes associated with benzene and the other VOCs.

A3.3 Health and proximity to petrol stations

Nine studies have investigated if there is a relationship between residential proximity to service stations and cancer. All have reported an increased risk. Most of the studies (n = 6) focussed specifically on childhood cancers, particularly leukaemia, one investigated cancer incidence for all ages and two focussed on adults. Each of the studies, and their findings are summarised below.

Table 1 Studies of childhood cancers and proximity to service stations

Country	Recruitment period	Ages	Outcome	Proximity to service station	Results Odds Ratio (95%CI)
UK [25]	1990 - 94	<15 yrs	Leukaemia	<100m v >100m	1.99 (0.73 – 4.23)
France [26]	1995 – 99	<14 yrs	Leukaemia	Adjacent	4.00 (1.50 – 10.30)
France [27]	2003 – 04	<18 yrs	Leukaemia	Adjacent	2.10 (1.10 – 4.00)
Switzerland [28]	2000 - 15	<15 yrs	All cancer Leukaemia	<50m v >500m	1.77 (1.05 – 2.98) 1.06 (0.32 – 3.51)
Italy [29]	1998 - 2019	<14 yrs	Leukaemia	<50m v >1000m	2.20 (0.50 – 9.40)
Taiwan [30]	1996 - 2006	<14 yrs	Leukaemia	Petrol station density/km^2	1.91 (1.29 – 2.82) Most v least PSD/km^2

A combined analysis (meta-analysis) was conducted for the first four studies [28]. Meta-analyses combine the results from various small studies that may have been underpowered (small sample size) to determine if there is a statistically significant effect. The OR (95%CI) of the combined analysis was 2.01 (1.25 – 3.22).

Table 2 Studies of cancer in adults, and all ages, and proximity to service stations

Country	Recruitment period	Ages	Outcome	Proximity to service station	Results Odds Ratio (95%CI)
Portugal [31]	2000 - 02	All	Lymphoma and Leukaemia	Varying distances	Cancer incidence elevated above background up to 75m from service stations (see Fig 1)
Taiwan [32]	1997 - 2006	Females 50 – 69 yrs	Lung cancer	Petrol station density/km^2	1.19 (1.02 – 2.82) Most v least PSD/km^2
Taiwan [33]	1997 - 2006	50 – 69 yrs	Bladder cancer	Petrol station density/km^2	1.22 (0.94 – 1.60) Most v least PSD/km^2

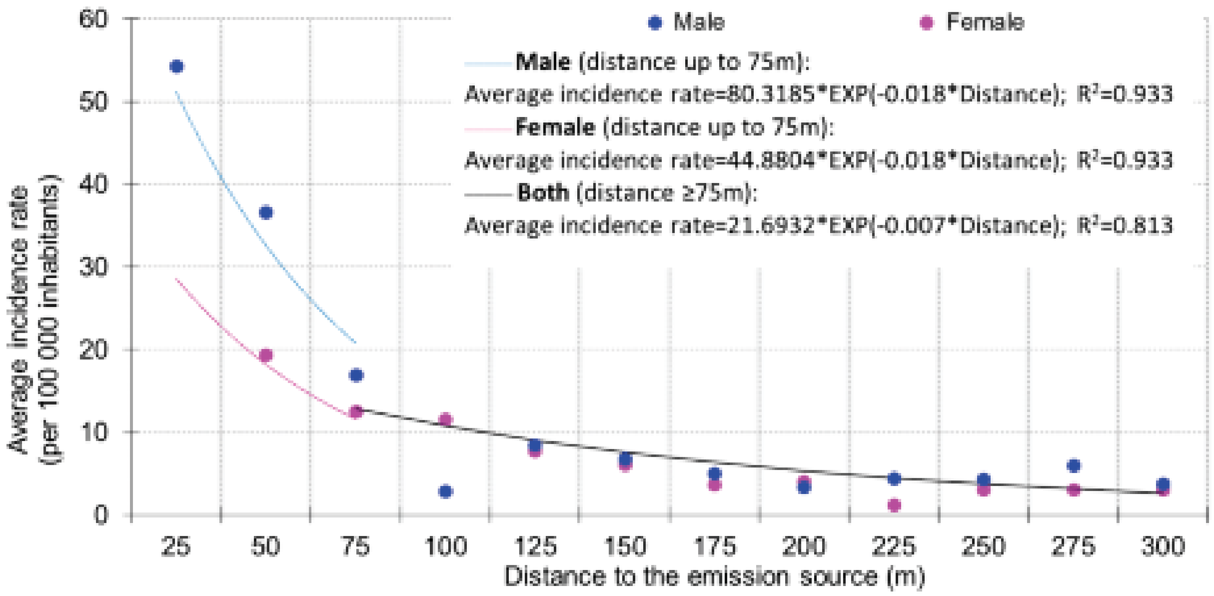

Figure 1: Annual incidence rate of lymphoma and leukaemia between 2000 and 2002 in Oporto, Portugal, relative to distance of residence from service stations [31]

Exposure for all these studies was based on residential proximity to service stations, not quantifiable benzene or other VOC exposure concentrations. Although 'close proximity' varied between studies (from adjacent to within 100m), the most recent evidence suggests that risk is increased at least within 50m of service stations.

None of the studies report the operating hours of service stations. Nor do they report on the use of vapour recovery technology (VRT). However, most studies were conducted after VR1, which captures displaced vapours from storage tanks when a tanker delivers petrol to a service station, had been introduced. For example, VR1 was introduced across most of Europe from the mid-1990s (Stage I petrol Directive 94/63/EC) and in Taiwan in 1997. Of the studies included above only the studies from the UK and France that were conducted in the 1990s may have included service stations with no VRT.

Conclusion: Residential proximity to service stations is associated with increased risk in cancer, particularly childhood leukaemia, and other health outcomes. A combined analysis of studies of childhood leukaemia and residential proximity to service stations suggests there is a doubling of the risk of leukaemia for children living in close proximity to service stations. ‘Close’ proximity is not well defined, but the most recent evidence suggests that there is an increased risk for those living within at least 50m of a service station. The increased risk could extend beyond 50m.

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