Toxicology and the New Zealand Farmer

A guide to common poisons on the farm

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Toxicology and the NZ Farmer

POISON!

This work is designed as a short introduction to common poisons found around New Zealand farms. It has been prepared to fulfill, in part, the requirement of the Kellogg Rural Leadership Programme.

Toxicology is the study of poisons. You may have heard the old saying "the dose makes the poison". This means that actually, everything is toxic at some level which makes the study of toxicology relevant to a number of areas including human health, the environment, public policy, drug development and human safety.

This booklet covers some of the chemicals found around the common New Zealand farming environment. The information on what to include has been based on analysis of statistics from the New Zealand National Poisons Centre.

Stay Safe

Key Points

- Store medicine and chemicals safely and out of the reach of children and pets.
- Follow the instructions on packaging
- Use personal protective equipment routinely
- If needed, wash personal protective equipment separately from other laundry
- Always keep medicines and chemicals in their original packaging
- Get rid of unused medicines and chemicals promptly and correctly (information on this is available from the poisons information centre or your local pharmacy)
- Work in well ventilated spaces wherever possible
- Learn how to do CPR

Know the number of the National Poisons Centre

0800 POISON (0800 764 766)

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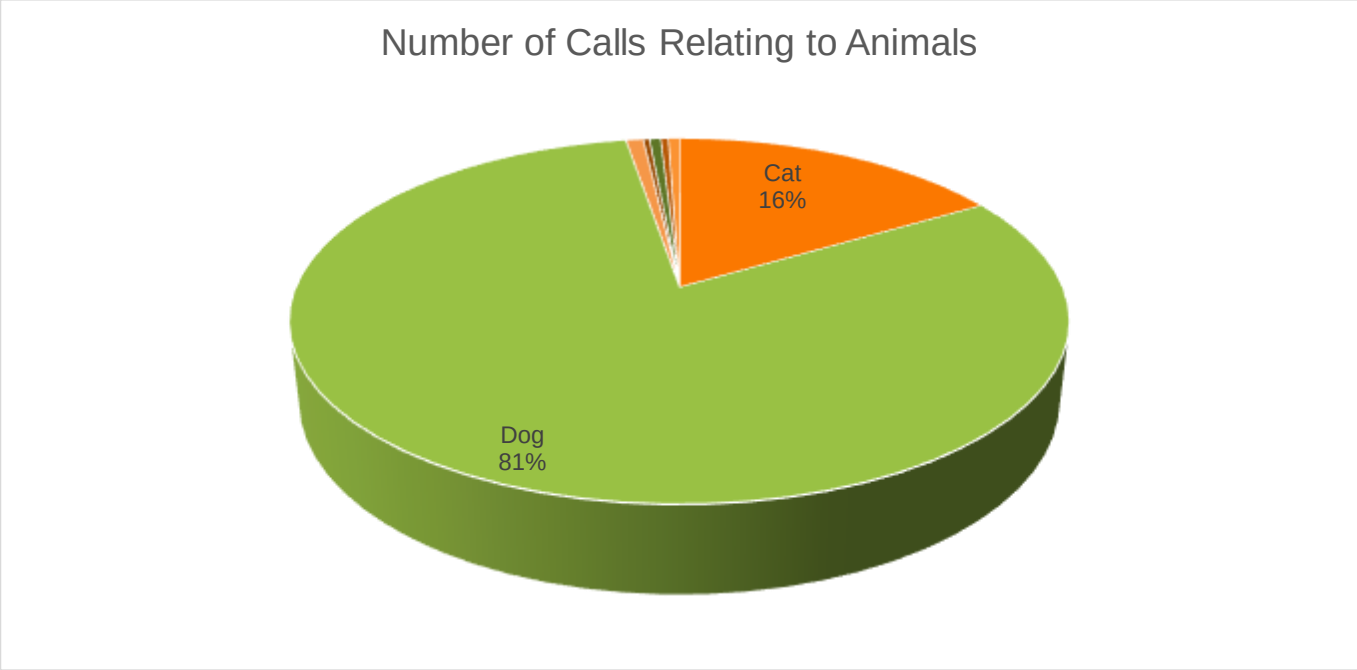
1. Statistics

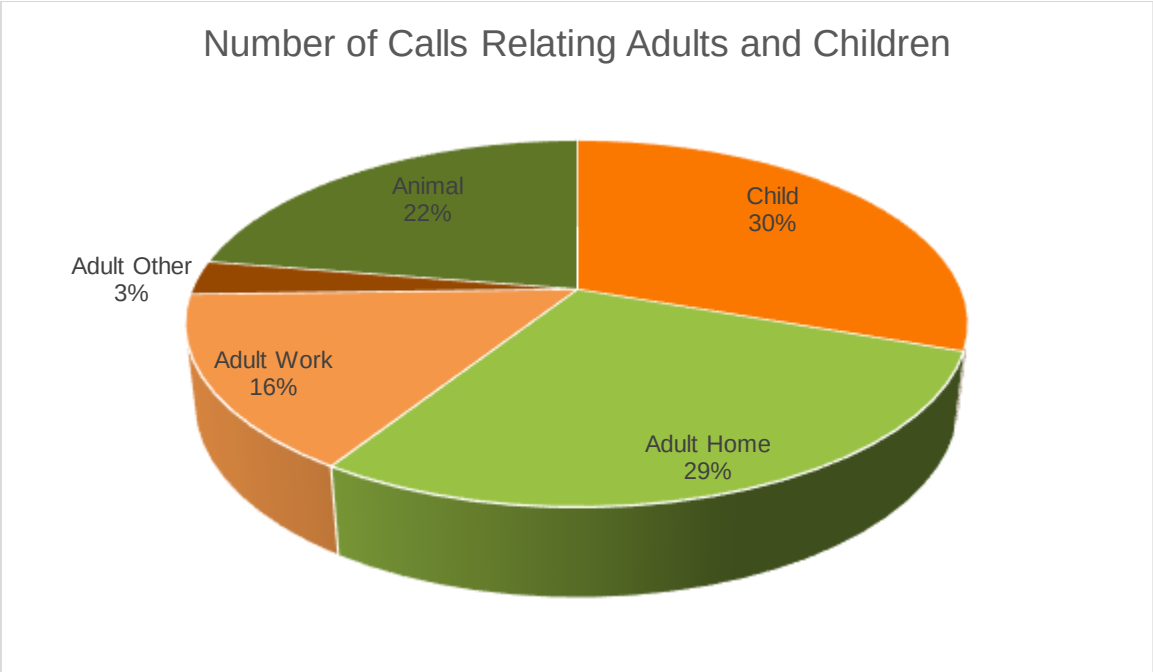
Crunching the numbers

In the period from January 2010 to January 2015 over 20,000 calls were received by the NZ National Poisons Centre relating to agricultural substances. This dataset has been analysed to determine the most common types and causes of poisoning reported in NZ.

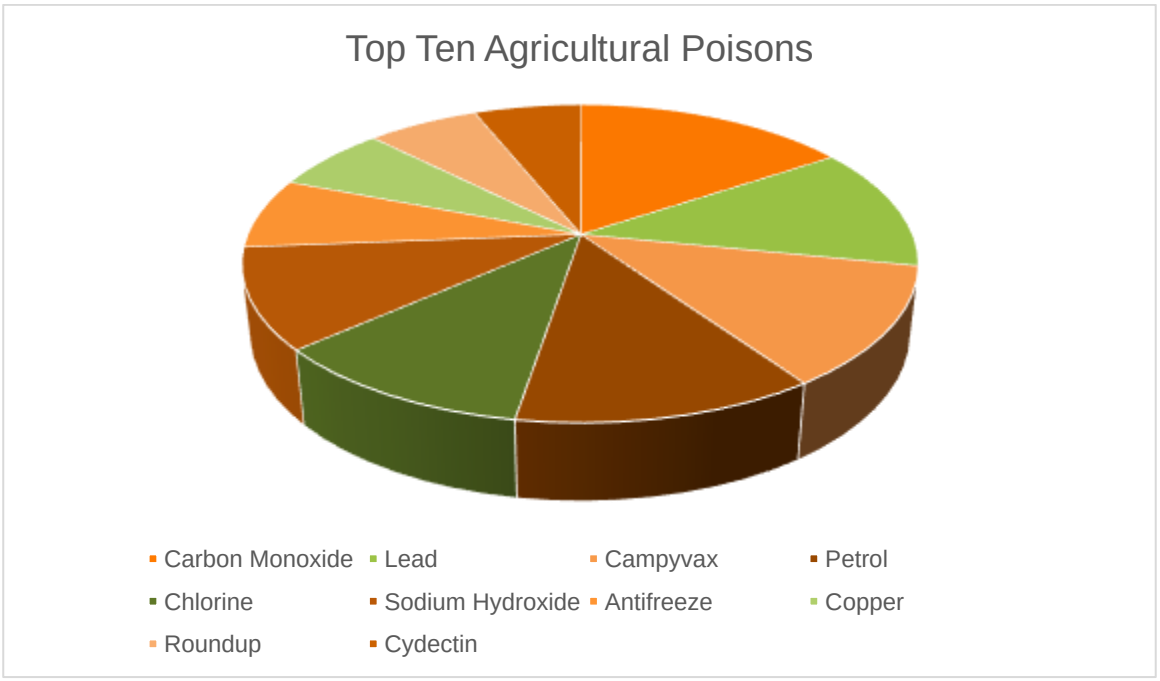
Seventy-eight percent of these enquiries related to human exposure (16,098 calls) while the remainder were regarding animal exposures (4,520). The most common animal exposures reported were for dogs with over 3,000 calls as compared to only 742 for the next commonest species, cat. Cattle and sheep accounted for 42 calls. The calls relating to cattle and sheep were predominantly related to exposure to roundup (glyphosate) or drenches/vaccines.



For humans, it was important to include statistics for both the home and workplace as the farm environment often encompasses both locations. In the statistics 3279 calls were reported as being a poisoning in the workplace whereas 16313 calls were related to exposures at home. Because of the inclusion of the home statistics there were a number of child poisonings included in the data set. Over 6000 calls related to child poisonings, most due to exposure to agricultural chemicals in sheds or storage facilities. Some of these calls also related to exposure to chemicals sometimes found in the home but often classed as agricultural such rat baits. Most of the calls (19,921) related to an acute exposure and only 697 to chronic. This classification was based on self-reporting rather than pre-defined criteria.



Of the 6114 calls relating to adult exposures 1828 were sufficiently serious to warrant medical attention. The level of medical input is not reported but is listed as active investigation or medical treatment required. This subset of calls needing follow up medical treatment was analysed to determine the agricultural chemicals that result in the most harm. The analysis identified 112 different chemicals. The top ten of these, shown in the graph below, accounted for approximately 30% of all reports requiring medical attention. Exposure to carbon monoxide (118 calls) was the most commonly reported poisoning that required a medical referral or further investigation.



2. Carbon monoxide

Vehicle Fumes

Carbon monoxide exposure most often occurs because of breathing in exhaust fumes in a confined space. Burning carbon fuels such as petrol and diesel releases carbon monoxide that builds up if an area is not well ventilated. Toxic exposures have been linked not only to petrol but also with BBQs, LPG heaters, coal fires, blocked chimneys and smoking (Cobb *et al.*, 1991). Indirect exposure can happen through the use of paint strippers (methylene chloride) and other industrial solvents which the body converts internally into carbon monoxide (Fagin *et al.*, 1980).

Carbon monoxide poisoning is one of the most common poisoning incidences worldwide (Garg *et al*., 2014). Mirroring overseas reports, the calls received by the National Poisons Centre relating to carbon monoxide followed exposure through exhaust fumes. Carbon monoxide is toxic because it reduces the ability of the blood to transport oxygen. Normally, breathing pulls oxygen into the body. This is moved around to various tissues and organs for use by the molecule haemoglobin. Carbon monoxide looks very similar to oxygen and so it will bind to haemoglobin but stops oxygen from binding and once bound carbon monoxide is difficult to remove. The tissues and organs start to suffer oxygen deprivation (Rose *et al.,* 2017). The symptoms of toxicity relate to this lack of oxygen; headache, shortness of breath and confusion. If exposure persists a bright pink or cherry red colour often forms around the mouth, caused by the change in colour of the haemoglobin when carbon monoxide binds (Rose *et al.,* 2017).

The unborn foetus is at particular risk. This is because foetal haemoglobin is designed to be more attractive to oxygen than adult haemoglobin. This allows the foetus to “pull” oxygen off the mothers haemoglobin and into its own tissues (Friedman *et al.,* 2015). However, this also happens with carbon monoxide. Therefore, a foetus will accumulate higher levels of carbon monoxide, and be more likely to suffer poisoning, following exposure (Friedman *et al,* 2015). This is one of the many reasons that pregnant mothers should avoid smoking during pregnancy. The buildup of carbon monoxide in the unborn child leads to ongoing health issues and mental retardation (Grandjean *et al.,* 2014).

Symptoms of toxicity

Symptoms of carbon monoxide poisoning can include:

- Headache
- Dizziness
- Nausea
- Convulsions
- Breathing difficulties
- Cherry red appearance

Where can I be exposed?

- Smoking
- Vehicle exhaust
- LPG heaters
- Welding
- During plastic molding
- Fire/burning in an unventilated space

What do I need to know to stay safe?

Carbon monoxide exposure is a leading cause of poisoning in New Zealand, both via intentional and unintentional exposure (McDowell *et al.,* 2006). The Poisons Centre recommends the following:

- Regularly check fireplaces, heaters and vehicles to ensure exhaust systems are working
- Clean fireplace flues regularly
- Do not run car engines in a garage even if the door is open
- If using gas heaters, ensure the house is well ventilated
- Never use an outside cooker or BBQ, gas or wood, inside the home
- Install carbon monoxide detectors in the home (often included as part of a fire alarm)

(Information for this section was complied with reference to Worksafe NZ, 2017)

3. Lead

Paint

Lead exposure can happen through a number of different routes including via food, dust, water, air pollution and paint. The calls received by the National Poisons Centre relating to lead were mostly following exposure to leaded paint. Lead is toxic to all living organisms but for humans the most susceptible are unborn children (foetus), neonates and toddlers. Exposure up until the age of 6 years old has been linked with long-term effects on mental health (Schwartz, 1994).

Lead is a neurotoxin, it affects the brain and nervous system by preventing signals passing smoothly between the brain and other organs and extremities (feet, hands etc). In adults, this means that they can lose strength in their arms and wrists (historically referred to as foot-drop or wrist-drop) (Mason, *et al*. 2014). These effects are most often seen following acute (short-term), high level exposures in occupational settings e.g. workers in lead metal smelters, steel welders, rubber and plastics factory workers and battery manufacturers. At lower levels of exposure will perform poorly on tasks requiring manual agility (Mason, *et al.,* 2014; ATDSR, 2007). Ongoing exposure to lead has also been linked to hypertension or high blood pressure (Wildemann *et al,* 2016). While exposure to lead has decreased markedly in the last two decades, due to the removal of lead-based products from petrol, significant exposure can still occur via sanding or removing lead based paints.

Exposure to lead is a particular concern for pregnant mothers, young infants and toddlers. The neurotoxic effects of lead target the developing nervous system and cause long-term damage.

Low level chronic (long-term) exposure shows up as decreased IQ levels caused whereas high levels cause severe brain damage, nausea, loss of appetite and loss of balance. Ongoing issues can include epilepsy, mental retardation and blindness. Acute toxicity in children is most often associated with a polluted environment or mothers being exposed in a high lead workplace (ATDSR, 2007). Chronic exposure is of ongoing concern, despite the reduction in most countries of air lead levels. Exposure through soil is becoming an increasing issue in developed countries but the effects of this can be mitigated through good hygiene practices such as routine hand-washing after contact with soil and prior to eating (Laidlaw *et al.,* 2017)

Symptoms of toxicity

Symptoms of lead poisoning are often non-specific but can include:

- Stomach pains
- Difficulty Sleeping
- Constipation
- Loss of appetite
- No symptoms (particularly children who may still suffer long-term effects)

Where can I be exposed?

- Removing lead paints
- Contact with soil containing lead
- Consumption of foods grown in contaminated soil
- Soldering steel
- Lead shots/sinkers (if making them yourself)
- Environment (e.g. living near to a lead or bronze smelter)

What do I need to know to stay safe?

The Ministry of Health reports that most lead exposure in NZ happens through the removal of older lead-based paints. When removing paint on any building built prior to the 1980's it is advised that you take the following precautions:

- Wear overalls and hair cover or hat that can be disposed of after use
- Wear an appropriate dust regulator (AS/NZS 1716:2012 (Respiratory Protective Devices)
- Remove overalls/hat when moving away from the work area
- Wash hands and face thoroughly before eating or drinking or touching children
- Do not smoke while working as it may increase transfer of dust to the mouth
- If indoors, remove all furnishings so they don't accumulate lead-contaminated dust
- If outdoors, close all windows and doors to prevent dust blowing inside
- Use a groundsheet to collect dust and scrapings and use a commercial vacuum to clean the area around the dust sheet
- Wipe down sanded areas and vacuum
- Wrap up all debris and dispose of immediately, consult your local council about disposal
- DO NOT BURN DEBRI
- KEEP CHILDREN AND PETS AWAY FROM THE WORKSPACE

(Information for this section was complied with reference to Ministry of Health, 2016)

4. Campyvax and Toxovax

Animal Vaccines

Vaccines are routinely used on the farm to ensure good animal health. Given by injection (subcutaneous or intramuscular) they contain virus, bacteria or parasites that cause an immune response in the animal and prevent future illness (Scott, 1997). Over 5% of all calls to the National Poisons related to exposure to one of these vaccines. However, the risk of toxicity is rare. The high referral rate for these preparations is due to the risks associated with a needle injury.

Although these products contain virus, bacteria or parasites that might be expected to be dangerous, these active agents are attenuated or killed during vaccine preparation. This means that the risk of an infection with the vaccine component is generally very low (Meeusen, 2007). However, if a farmer or worker accidentally cuts or injures themselves with the needle it must be referred for medical attention as the needle is likely to be contaminated. Therefore, the highest risk with the vaccines is infection around the injection site or the development of tetanus (Poisons Information Centre, 2017). There is a small risk of a severe immune reaction (e.g. anaphylaxis) to the vaccine preparation. Many vaccines contain additional agents that help activate the immune system or stabilise the solution to allow for easy storage and shipping (Spickler *et al.,* 2003). In some people these additional chemicals can trigger a serious allergic response that can lead to hospitalisation (Chung, 2014). The symptoms include a rash, swelling, low blood pressure, increased heart rate, difficulty breathing. Any of these symptoms

should be taken seriously and monitored closely as allergic reactions can become life-threatening very quickly (Chung, 2014).

Symptoms of toxicity

- Inflammation around the injection site
- Allergic reaction: rash, swelling, feeling faint, increased heart rate, difficulty breathing
- Tetanus: stiffness around neck, jaw, back, stomach, arms, legs, fever, muscle spasms or difficulty breathing

Where can I be exposed?

- During vaccine administration
- Tetanus is bacteria found in soil, exposure is through contamination of a cut or wound

What do I need to know to stay safe?

- Risk is due to infection via cut with dirty or contaminated needle
- Infection or an allergic response can result
- If needle has been used on animals, other diseases may be transferred through the needle injury
- If allergic symptoms develop. Monitor and be prepared to act quickly
- Being fully immunized against tetanus will reduce the chance of any cut being infected by the tetanus bacteria.
    - Children are offered free immunisations that include tetanus at 6 weeks, 3 months and 5 months old
    - A booster should be given at 4 and 11 years old.
    - A further booster is available at 45 and 65 years old
    - Tetanus boosters are also often recommended after a cut, graze or wound and are free of charge (although you may have to pay a consultation fee)

(Information for this section was complied with reference to Ministry of Health, 2014)

5. Petroleum

Petrol and Turps

The risks of exposure to burning petrol fumes (exhaust) have been covered under “Carbon Monoxide”. This chapter will focus on other poisoning exposures such as by breathing petrol vapours, by ingestion (drinking) or via the skin. The data from the National Poisons Centre highlight these scenarios as the reason for the majority of calls relating to petrol. This section also covers mineral turpentine as many of the constituent chemicals are the same.

Petrol and mineral turpentine contain a mix of chemicals grouped together under the term hydrocarbon. All products derived from oil contain hydrocarbons of different composition and length (Speight, 2005). Petrol contains hydrocarbon chains mainly consisting of 4 to 12 carbon molecules which include known toxic agents such as benzene and xylene (Speight, 2005). However, variation in its composition means that toxicity can vary from day to day, location to location and person to person (Caprino and Togna, 1998). Mineral turpentine is slightly more refined containing hydrocarbons with 7 to 12 carbons as well as benzene. When assessing the toxicity of mixtures, it is common to measure individual components and assess the toxicity of each chemical. This has led to a list of possible symptoms associated with petrol inhalation or ingestion including: development of cancer (kidney or liver), skin and eye irritation, effects on the brain (CNS depression) and heart disease (Caprino and Togna, 1998).

Key constituents in petrol in terms of toxicity are methyl *tert*-butyl ether (MTBE), methanol, benzene and xylene. MTBE has replaced lead as an octane booster in fuels. Octane booster

are oxygenators that help ensure the complete combustion of fuel and thereby reduce emissions in the exhaust (Bongradt, 1998). In animal studies MTBE is a proven carcinogen causing renal tumours in male rats and liver tumours in female rats (Ahmed, 2001; Burns *et al.,* 2012; Mennear, 1997). However, there is ongoing debate as to the relevance of these results to human exposures with many researchers reporting little or no evidence for petrol exposures causing cancer in humans (Mennear, 1997; Caprino and Togna, 1998; Bingham *et al.,* 1979; Awasthi *et al.,* 2016). From a toxicologist's point of view, there is currently not enough evidence to cause concern about the carcinogenic risk to humans of MTBE at levels found in petrol.

Methanol and ethanol (alcohol) are both present in petrol at differing levels. They can both cause CNS depression (drowsiness) but are also broken down in the body to toxic substance (aldehydes and acetic acids) (McMartin *et al.,* 2016). Alcohol is present at much lower levels than is commonly ingested by choice and is unlikely to contribute to petrol toxicity (Pohanka, 2016). Methanol is linked to headaches, nausea, vomiting, blindness, confusion and possibly death (Adewole, 2016). In cases of acute, high dose ingestion of alcohol these symptoms may be relevant however it is in fuels at very low levels and so unless a significant quantity of regular petrol is consumed methanol toxicity is unlikely to occur. Newer biodiesels and alcohol fuels can contain up to 10% methanol content (Liu *et al.*, 2007). At this level around 100ml of fuel may contain sufficient methanol to be toxic to the average adult (less in a child) (Tephly, 1991)

Benzene primarily affects the blood and red blood cells (haemotoxicity). It is also a known carcinogen causing leukaemia, a cancer that affects the bone marrow and therefore the production of red blood cells. While the levels of benzene in petrol and mineral turpentine are regulated (less than 5% of additive for petrol and less than 0.1% for turpentine), the toxicity is sufficient to be of concern with some researchers calling for a 0.00001% (0.1ppm) threshold limit value (Yardley-Jones *et al.,* 1991). Many scientists believe that there is no safe exposure limit for carcinogens such as benzene and so exposure to even small amounts, particularly on a regular basis, is cause for concern. Exposure to benzene is a significant hazard when dealing with petrol. Benzene is volatile so will be present in petrol vapours as well as the liquid form (National Centre for Biotechnology Information, 2017). People who work with petrol and organic solvents (e.g. turpentine) regularly are at the greatest risk of toxicity caused by this chemical.

Toluene is present in petrol at levels of 5-7% (ATSDR, 2015) and is a known neurotoxin. It causes a range of effects in the brain with symptoms of toxicity ranging from slight dizziness and headache through to difficulty breathing and death (ATSDR, 2105). These effects can occur from both inhalation (breathing in petrol vapour) or through the skin (splashing petrol on bare skin or not removing contaminated clothing). Long-term low-level exposure can cause mental health and hearing problems especially in children (Tormoehlen, 2014). Long-term effects on mental health in adults have been reported at levels of 100ppm (0.01%), much less than levels found in petrol (Tormoehlen, 2015). However, these studies are relevant occupational exposures, such as people working in petrol stations, rather than a one-off exposure. For an acute event (e.g. a petrol spill) adverse effects such as breathing difficulties have been noted at toluene levels above 200ppm (0.02%) with some susceptible people reacting at levels as low as 50ppm (0.005%) (ATSDR, 2015). Severe effects on breathing, brain function, hearing, kidney, liver and other organs can occur at concentrations above 300ppm (0.03%) and exposure to 500ppm (0.05%) for more than ten minutes is associated with a

significant chance of long term health effects and death (ATSDR, 2015). This makes toluene a key chemical when considering the overall toxicity of petrol. Most of the effects seen with short term exposures (difficulty breathing and headaches) are linked to the amount of toluene present. The long-term effects (cancer, effects on the brain, kidney, liver and other organs) are most relevant to those working with petrochemicals daily but may be of concern to agricultural workers who are often refueling equipment and machinery.

Symptoms of toxicity

- Difficulty breathing (if inhaled) or skin irritation (if contact)
- Headache, nausea, vomiting, dizziness
- Coughing, choking, gasping, drowsiness (seek medical attention)
- Symptoms may take up to 30 minutes to appear

Where can I be exposed?

- Petrol re-fueling
- Spill or another unexpected event
- During maintenance operations

What do I need to know to stay safe?

- Petrol is extremely toxic and an ever-present hazard
- If petrol is swallowed seek medical advice or ring the Poisons Centre.
    - DO NOT INDUCE VOMITING
- If a spill occurs onto clothing, remove clothing and rinse skin
- If irritation or rash develops seek medical advice
- For inhaled fumes, relocate to a non-contaminated area
- Monitor for symptoms of drowsiness and dizziness
- Seek medical attention if necessary
- Keep all products containing petrol or solvents out of reach of children
- Prolonged exposure to fumes and liquid is associated with an increased risk of cancer
- Always wash hands thoroughly after dealing with liquid petrol and solvent
- Use an approved respirator if appropriate
- Never transfer into empty food or drink containers such as soft drink bottles or water bottles

(Information for this section was complied with reference to Caltex MSDS sheet unleaded petrol, 2015)

6. Chlorine

Bleach

The most common domestic use of chlorine is as a swimming pool treatment. Tablets and liquid preparations are readily available. Chlorine is also used as a bleach, disinfectant, in the production of paper, plastic, fabrics, solvents and paints. Toxicity can occur through swallowing, eye contact and though breathing the fumes. Additionally, chlorine fumes can be produced when dissolving a solid powder or when mixing chlorine-based bleaches with acids. For example, hypochlorite bleach mixed with many toilet cleaners (acidic) will release chlorine gas. A range of scenarios is recorded in the national Poisons Centre data and most involve preparations of chlorine used as a bleach or swimming pool treatment.

Chlorine is an irritant and causes a range of symptoms depending on the tissue and the route of exposure (Winder, 2001). The most likely route of exposure is through inhalation of chlorine gas which is given off when chlorine liquid is exposed to air or when solid chlorine tablets are mixed with water (Winder, 2001). Exposure to chlorine gas causes difficulty breathing, coughing, and at higher doses a feeling of restricted or obstructed breathing due to fluid accumulation in the lungs (Das and Blanc, 1993). Chlorine is highly soluble in water and so will be absorbed into the tissues lining the nose, throat and mouth to cause toxicity and irritation. Long term, low level exposure may cause asthma and other respiratory sensitivities (Das and Blanc, 1993). Spilling chlorine granules on the skin can cause burns, irritation, redness and swelling (Winder, 2001). If a chlorine product is swallowed (e.g. drinking bleach or ingestion of swimming pool tablets) then likely symptoms include burns to the mouth and throat, coughing, stomach pains (Arevalo-Silva,

et al., 2006). In most cases, as long as the amount taken isn't large, the symptoms can be managed and very few long-term health problems result (Arevalo-Silva, *et al.,* 2006).

Symptoms of toxicity

- Burns or irritation to skin, mouth, throat or eyes
- Blistering or swelling around contact area
- Difficulty breathing (if exposed to fumes or swallowed)
- Possible increased heart rate and high blood pressure

Where can I be exposed?

- When using chemicals such as bleach and swimming pool treatments
- When mixing a hypochlorite bleach with an acid
    - For example, bleach and toilet cleaner mixed can release chlorine gas
- When mixing swimming pool tablets with other liquids
- After prolonged storage of chlorine tablets in sealed container, gas can accumulate and release explosively
- Chlorine dioxide can release chlorine gas when mixed with water
- In a work environment when using bleaches and other chemicals that include chlorine

What do I need to know to stay safe?

- Always wear the appropriate personal protective equipment when using chlorine which may include:
    - Gloves
    - Eye protection such as safety glasses
    - Using an approved respirator
- Follow the manufacturer's directions for storage and use as stated on the packet
- Work in a well-ventilated area
- For inhaled fumes, relocate to a non-contaminated area immediately and seek medical advice
    - In the case of a large spill, move to higher ground as chlorine gas is heavier than air.
- If swallowed seek medical advice or ring the Poisons Centre
    - DO NOT INDUCE VOMITING
- If splashed on clothing, remove (cut-off) clothing immediately and wash area thoroughly with soap and water
- If splashed on skin or eye wash thoroughly under lukewarm running water and seek medical advice immediately
- Keep children and pets away from any areas where sodium hydroxide is being used
- Store in clearly labelled, sealed containers, well out of the reach of children and pets
- Never transfer into empty food or drink containers such as soft drink bottles or water bottles

(Information for this section was complied with reference to Centers for Disease Control, 2013)

7. Sodium Hydroxide

Drain Cleaner/Caustic Soda

Sodium hydroxide is the main component of most drain cleaners and oven cleaners. It is also used in soap making, metal processing, plastic manufacture, oil refining and water treatment. Calls to the Poisons Centre relate to splashes in the eye, inhaling fumes and also accidental ingestion. All these situations are possibly dangerous.

Sodium hydroxide is available as both solid pellets and a liquid and is commonly used as a powerful cleaning agent. However, it is also a very strong base and as such can causes burns and skin irritation (Emoto *et al.,* 2015). A small splash on skin may result in local irritation but for anything beyond minor redness should be seen by a doctor or other medical professional (Ramasamy, 2003). Similar to chlorine, there are no real long term toxicity issues with sodium hydroxide. The direct corrosive effects of the chemical generally resolve without complications as long as exposure isn't too high (Emoto *et al.,* 2015). However, severe burns can result from contact with sodium hydroxide and so care must be taken at all times.

Symptoms of toxicity

- Burns or irritation to skin, mouth, throat or eyes
- Difficulty breathing (if exposed to fumes or swallowed)

Where can I be exposed?

- When using chemicals such as drain and oven cleaners
- When preparing a sodium hydroxide solution from pellets
    - Always add the pellets to cold water, not water to pellets
- In a work environment when using cleaning chemicals and other preparations that include sodium hydroxide

What do I need to know to stay safe?

- Always wear the appropriate personal protective equipment which may include:
    - Gloves (not thin rubber, nitrile or PVC gloves)
    - Eye protection such as safety glasses
    - Using an approved respirator
    - Wear an apron, long sleeves/trousers, or protective layers such as lab coats/overalls
- Follow the manufacturer's directions for storage and use as stated on the packet
- Work in a well-ventilated area
- If swallowed seek medical advice or ring the Poisons Centre
- If splashed on clothing, remove (cut-off) clothing immediately, shoes and jewellery (watches etc), blot or brush away any excess chemical
- If splashed on skin or eye wash thoroughly under lukewarm running water for 1 hour and seek medical advice immediately
- For inhaled fumes, relocate to a non-contaminated area
- Keep children and pets away from any areas where sodium hydroxide is being used
- Store in clearly labelled, sealed containers, well out of the reach of children and pets
- Never transfer into empty food or drink containers such as soft drink bottles or water bottles

(Information for this section was complied with reference to Canadian Centre for Occupational Health and Safety, 2017)

8. Ethylene Glycol

Antifreeze

The main chemical component of antifreeze is ethylene glycol, an alcohol similar to methanol and ethanol covered in the previous section on petrol toxicity. The calls recorded by the Poisons Centre largely relate to ingestion (accidental or intentional) and splashes into the eye. While children are not included in the analysis to identify the top ten poisons covered in this paper, they are at high risk of toxicity following antifreeze ingestion. This is because antifreeze is typically brightly coloured and tastes sweet. Children can accidentally consume large qualities without realising that it is harmful.

Ethylene glycol is easily absorbed through the stomach and intestines and less well through the eyes or skin (McDonald *et al.,* 1972). Once in the body it is rapidly converted to glycoaldehyde, glycolic acid, glyoxylic acid and oxalic acid all of which are toxic (Leth and Gergersen., 2005). These chemicals are all cellular toxins that cause a range of effects including central nervous system depression (drowsiness), heart failure and kidney toxicity (Cox and Phillips, 2004)). Immediately after swallowing ethylene glycol a patient may show signs of drunkenness or euphoria as the initial effects are similar to alcohol (ethanol) (Barceloux, *et al.,* 1998). Some people may experience nausea or vomiting but this is not always the case. These symptoms may decrease or even disappear entirely before cardiovascular effects are observed 1-2 days after consumption. Patients can experience an increased heart rate and increases in blood pressure, this is indicative of the poison being converted to the toxic components and starting to harm different body systems (Cox and Phillips, 2004). The last phase of poisoning are the

effects on the kidneys which can stop working, this typically occurs 1-3 days after ingesting the poison (Barceloux, *et al.,* 1998). A large number of poisonings worldwide are linked to the ingestion of ethylene glycol and anything more than a mouthful in an adult (or more than a lick in children) is concerned cause for referral to a medical practitioner. In all cases, early intervention is associated with better outcomes (McMartin *et al.,* 2016).

Symptoms of toxicity

- Difficulty breathing or rapid breathing
- Blurred vision
- Rapid heartbeat
- Coma, convulsions, fatigue, headache, slurred speech
- Nausea and vomiting
- Blue lips and fingernails
- Irritation to eye or skin at point of contact

Where can I be exposed?

- Through a spill or splash or antifreeze
- Through workplaces were ethylene glycol is used
- During maintenance operations

What do I need to know to stay safe?

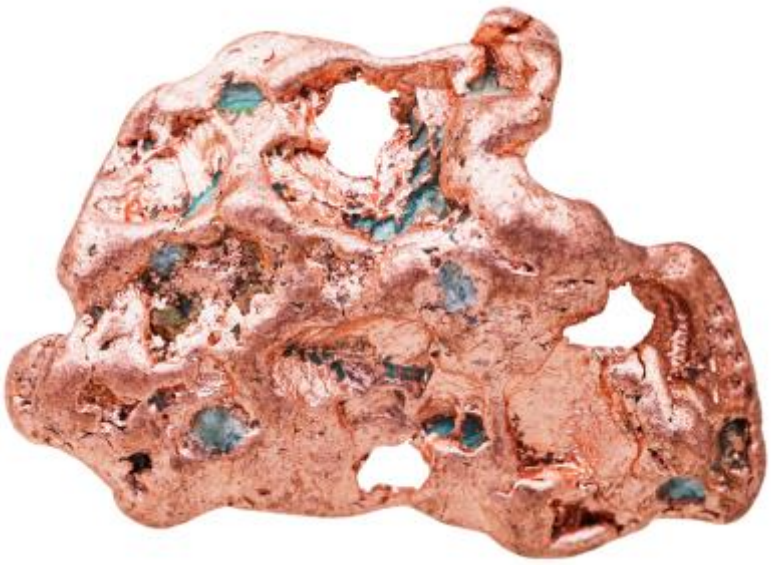
- Antifreeze is toxic and symptoms of toxicity may be delayed
- Antifreeze is a risk to children and pets
- Keep children and pets away while adding antifreeze
- Perform regular checks to ensure antifreeze is not leaking onto the garage floor
- If swallowed seek medical advice or ring the Poisons Centre
- If splashed on skin or eye was thoroughly and monitor
- If rash or irritation does not resolve within a day seek advice
- Clean up spills immediately to prevent ingestion by animals or children
- Store in clearly labelled, sealed containers, well out of the reach of children and pets
- Never transfer into empty food or drink containers such as soft drink bottles or water bottles

(Information for this section was complied with reference to U.S. National Library of Medicine, 2015)

9. Copper

Fungicide Sprays

Copper is essential for everyday body functions and is only moderately toxic. However, it's use in fungicide (copper hydroxide) and bactericide (as copper oxychloride) sprays means that exposure to large concentrations is possible. Indeed, callers to the Poisons Centre were concerned about symptoms following use of copper-based sprays, as well as exposure during animal treatment with vitamin health mixes (such as copperex injections).



In its pure form copper is a metal that is vital for many body functions including protection against oxidative damage and cancer. Toxic symptoms due to swallowing copper sulfate are rare as copper sulfate is an emetic and will generally cause immediate and powerful vomiting (Chuttani *et al.,* 1965). However, copper hydroxide and copper oxychloride are water soluble preparations of copper that are readily absorbed (Sabin, 2016). These forms of copper are more correctly termed the copper salts and generally have higher toxicity than pure copper (Husak, 2015). Toxicity has been reported at levels of 11mg/kg copper oxychloride (equivalent to ingesting around 200g of most copper pesticides containing 350 mg/kg copper salt). Exposure at this level can lead to rashes, itching skin, conjunctivitis in the eye, inflammation of skin or eye (Husak, 2015). The chronic effects of exposure to copper and copper salts include a variety of cancers as well as immune, blood, brain and reproductive disorders (Remor *et al.,* 2009). As mentioned previously, many researchers believe there is no safe lower limit of exposure for cancer causing chemicals. However, the data around cancer is insufficient to warrant the classification of copper as a carcinogen by the US Environmental Protection

Agency, International Agency for Research on Cancer or the US Occupational Health and Safety Administration (ATSDR, 2004; IARC, 1989; US EPA Cancer, 1986). It is important to note that these classifications are based on a lack of adequate data rather than proof of no effect (ATDSR, 2004). Long term copper exposure does cause a multitude of effects on other systems with the brain, liver and kidney being most at risk (Kumar *et al.* 2015). The toxicity of copper is most commonly associated with Wilson's or Menke's disease which involve a range of symptoms related to the imbalance of copper within the body (Gaetke *at al.,* 2014).

Symptoms of toxicity

- Itching skin, eczema
- Conjunctivitis
- Inflammation of eye or skin
- Nausea and vomiting, stomach pains
- Metallic taste in mouth

Where can I be exposed?

- Through copper-based fungicide sprays (e.g. Champ, Blue Shield, Kocide Blue, Oxicup)
- Through supplements containing copper
    - There is less of a risk of toxicity with the supplements as they contain lower levels of copper and ingestion levels are generally lower
- Through ingestion of copper sulfate
    - It is rare for this to result in significant full body toxicity
- Welding involving copper

What do I need to know to stay safe?

- Always wear the appropriate personal protective equipment which may include:
    - Waterproof gloves
    - Wear fully buttoned cotton overalls that fully cover arms and legs
    - Waterproof socks and shoes
    - Eye protection such as safety glasses
    - Using an approved respirator
- Wash protective clothing separately from other laundry
- Follow the manufacturer's directions for storage and use as stated on the packet
- Work in a well-ventilated area
- If swallowed seek medical advice or ring the Poisons Centre
- If splashed on clothing, remove clothing and discard
- If splashed on skin or eye, rinse with water
- Store in clearly labelled, sealed containers, well out of the reach of children and pets
- Never transfer into empty food or drink containers such as soft drink bottles or water bottles

(Information for this section was complied with reference to Rozman and Klaasen, 2007)

10. Glyphosate

Roundup™

The active ingredient in Roundup™ is glyphosate. First licensed in 1974 it has become a popular herbicide with some reports suggesting it is the most-used agricultural chemical ever (Newsweek, 2016). It is normally applied as a spray. Callers to the Poisons Centre were largely concerned about the toxicity of glyphosate following inhalation or spills.

Glyphosate is toxic to plants because it inhibits an enzyme (EPSPS) that is essential for protein production in plants but not humans. This means that it has high specificity for plants and exhibits relatively low toxicity in humans and animals (Williams *et al.,* 2000). It is considered non-toxic on contact with skin and only moderately toxic following ingestion (swallowing) (Williams *et al.,* 2000). It is estimated that adults will not suffer long term effects at exposures less than 85ml but this is very dependent on age and other parameters (Bradberry *et al.,* 2004). Children in particular are regarded as more vulnerable to glyphosate poisoning and should be seen by a medical professional if they swallow products containing glyphosate (Bradberry *et al.,* 2004). The reportedly low toxicity in adults is because glyphosate is not well absorbed, it is not metabolised by the body into other chemicals and it does not accumulate in tissues (Williams *et al.,* 2000). However, in 2016, the International Agency of Research on Cancer (IARC) revised the classification of glyphosate reclassifying it as chemical that is probably carcinogenic to humans (IARC, 2016). This decision was based on a growing body of evidence using human data (epidemiological studies) and suggests that workers should exercise caution when using these products even if the labelling suggests a low toxicity risk. Despite being considered non-

toxic via skin, irritation and dermatitis has been reported but these effects are often due to other chemicals present in the spray preparation, rather than the glyphosate itself (Bradberry, 2004). As mentioned previously under the “petrol” section, the effects of mixing chemicals to form commercial spray preparations makes it difficult to assess the true toxicity of a product. There have been reported, many in cell cultures rather than animal models or from human data, of severe toxicity caused by mixtures containing glyphosate as the listed active ingredient (Mesnage *et al.,* 2014; Mesnage *et al*., 2013; Gasnier *et al.,* 2009; Richard *et al.,* 2005; Benachour and Seralini, 2008). This range of studies suggests that there may be toxicity associated with individual commercial glyphosate preparations but at this stage there is insufficient data to establish a definite link.

Symptoms of toxicity

- Upset stomach
- Nausea, vomiting
- Following large exposures or in children:
- Burning of mouth and throat
- Stomach and abdominal pain
- Difficulty breathing
- Changes in heart rate

Where can I be exposed?

- During application of a glyphosate herbicide
- During preparation of a glyphosate herbicide

What do I need to know to stay safe?

- Always wear the appropriate personal protective equipment which may include:
    - Using gloves
    - Wearing clothes that fully cover arms and legs
    - Eye protection such as safety glasses
    - Using an approved respirator
- Work on a calm, non-windy day if possible
- Keep children and pets away from areas where glyphosate is being used
- Never eat or drink when applying the herbicide
- Wash hands and face thoroughly before eating or drinking or touching children
- Do not smoke while working as it may increase transfer of chemical to the mouth
- Avoid touching plants that are wet with glyphosate
- Do not let animals eat or touch plants that are wet with glyphosate
- Wash protective clothing separately from other laundry
- Follow the manufacturer’s directions for storage and use as stated on the packet
- Store in clearly labelled, sealed containers, well out of the reach of children and pets
- Never transfer into empty food or drink containers such as soft drink bottles or water bottles

(Information for this section was complied with reference to Henderson *et al.,* 2010)

11. Moxidectin

Drench

Drenches are widely used to manage the parasite burden of worms in stock. Classed as anthelmintics the active compound is generally either moxidectin (cydectin) or avamectin (ivermectin). These products are available in a range of formulations including as a drench, injection, tablet or paste. Callers reporting symptoms had normally been using the injection form of the drug and had experienced a needle stick injury. This requires the Poisons Centre staff to recommend the caller seeks medical attention due to the risk of tetanus.

Both moxidectin and avamectin have been reported as having low toxicity in humans (Cotreau *et al.,* 2003; Campbell, 1993). Immediate adverse effects include fever, dizziness and swelling around the site of exposure but these symptoms were generally mild and short-lived (Campbell, 1993). Moxidectin has been associated with short term effects on the brain including headaches, twitching, back pain and ear pain. However, again these were minor and resolved naturally within 1-2 days (Cotreau, 2003). The reason for the high referral rate to medical practitioner with this class of drug is largely due to the dangers of infection and contamination following and injury with a non-sterile needle. This is similar to the risk associated with the animal vaccines campyvax and toxovax.

Symptoms of toxicity

- Inflammation around the injection site
- Allergic reaction: rash, swelling, feeling faint, increased heart rate, difficulty breathing
- Tetanus: stiffness around neck, jaw, back, stomach, arms, legs, fever, muscle spasms or difficulty breathing

Where can I be exposed?

- During vaccine administration
- Tetanus is bacteria found in soil, exposure is through contamination of a cut or wound

What do I need to know to stay safe?

- Risk is due to infection via cut with dirty or contaminated needle
- Infection or an allergic response can result
- If needle has been used on animals, other diseases may be transferred through the needle injury
- If allergic symptoms develop. Monitor and be prepared to act quickly
- Being fully immunized against tetanus will reduce the chance of any cut being infected by the tetanus bacteria.
    - Children are offered free immunisations that include tetanus at 6 weeks, 3 months and 5 months old
    - A booster should be given at 4 and 11 years old.
    - A further booster is available at 45 and 65 years old
    - Tetanus boosters are also often recommended after a cut, graze or wound and are free of charge (although you may have to pay a consultation fee)

(Information for this section was complied with reference to Ministry of Health, 2014)

12. Insecticides

Chlorpyrifos™ and Ripcord™

Insecticides such as Nuvos and Ripcord do not make the top ten list because of the variety of brand names and different chemical groups associated with these products. However, close to 180 calls related to exposure to industrial pesticides and a further 193 related to household insecticides. These together (total calls 373) account for one of the largest groups requiring medical attention. For this reason, the toxicity of two major classes – the organophosphates and the pyrethroids – are briefly covered here.

Organophosphates

Organophosphate insecticides (and carbamate insecticides) target the cholinesterase enzyme that removes the signaling molecule acetylcholine (Ballantyne and Marrs, 2013). All animals use acetylcholine to signal from nerve to nerve but, being smaller, insects are more sensitive to smaller doses. The organophosphates insecticides were derived from nerve gases used in World War 2 such as sarin (Ballantyne and Marrs, 2013). By inhibiting the removal of acetylcholine, they disrupt signaling between nerves and can cause an increased heart rate, stomach cramps, difficulty breathing, hypertension, tremors, paralysis and seizures (Bardin *et al*., 1994). The degree of symptoms is related to the dose with increasing doses being acutely toxic and sometimes fatal. Symptoms may persist for several months following an exposure with ongoing problems with brain and muscle function of most concern (Marrs, 1993). It is important to note that the carbamate insecticides have a different pattern of toxicity, and show different symptoms after exposure to the organophosphates even though they both inhibit the

acetylcholinesterase enzyme (King and Aaron, 2015). In children, the neurological effects of organophosphates may cause long-term changes to their biology which can result in mental impairment, growth impairments and long-term respiratory illness such as asthma (Eskenazi *et al.,* 1999). The level at which this occurs is still under debate but it is accepted that children, infants and fetuses are highly susceptible to the effects of organophosphates (Eskenazi *et al.,* 1999).

Pyrethroids

Pyrethroid insecticides were originally synthesized from the naturally occurring pyrethroids found in chrysanthemum flowers. Following a long period of development there are now a wide range of pyrethroid insecticides available with targeted toxicity towards specific species (Rozman and Klaasen, 2007). The mechanism by which these compounds work is more complex than the organophosphates but also involves the inhibition of nerve signals. Pyrethroids modify the activity of the voltage-dependant sodium channels. These channels mediate a range of effects in the body but a core function is in transmitting a nerve impulse along a nerve (e.g. from the brain to the hand). By interfering with these channels the insecticide stops nerve signals from travelling and cause toxicity (Vijverberg and anden Bercken, 1990). Poisoning from pyrethroids is less common than with the organophosphates however treatment can be difficult and the duration of symptoms can be longer than expected (Ray *et al.*, 2000). Symptoms are grouped into two classes: type I pyrethroids induce tremor and hyper-excitability of muscles whereas type II cause increased saliva production, twitching, muscle twisting and seizures (Ray *et al.*, 2000). These symptoms may be worse if the patient has also been exposed to an organophosphate (Ray et al., 2000).

Symptoms of toxicity

- Changes in heart rate
- Muscle tremors, shaking or seizures
- Difficulty breathing

Where can I be exposed?

- During spraying or preparation of insecticides

What do I need to know to stay safe?

- Always wear the appropriate personal protective equipment which may include:
    - Using gloves
    - Wearing clothes that fully cover arms and legs
    - Eye protection such as safety glasses
    - Using an approved respirator
- Work on a calm, non-windy day if possible
- Keep children and pets away from areas where insecticides are being used
- Never eat or drink when applying the insecticide
- Wash hands and face thoroughly before eating or drinking or touching children
- Do not smoke while working as it may increase transfer of chemical to the mouth

- If necessary, wash protective clothing separately from other laundry
- Follow the manufacturer's directions for storage and use as stated on the packet
- Store in clearly labelled, sealed containers, well out of the reach of children and pets
- Never transfer into empty food or drink containers such as soft drink bottles or water bottles

List of some common pesticides and their chemical groups

Commercial Name	Chemical Group
BIFLEX AQUAMAX INSECTICIDE	Pyrethroid
CARBARYL	Carbamate
CATERKIL 1000	Organophosphate
CHLORPYRIFOS	Organophosphate
CISLIN	Pyrethroid
CONFIDOR	Neonicitinoid
COUNTER 10G	Organophosphate
DELTAMETHRIN	Pyrethroid
DEW	Organophosphate
DIAZINON	Organophosphate
FICAM	Carbamate
FIPRONIL	Pyrazole
FURAKOTE 400	Carbamate
GESAPON 20G	Organophosphate
KARATE	Pyrethroid
KEY DELTA AQUA	Pyrethroid
LORSBAN	Organophosphate
MAGGO	Pyrethroid
MALATHION	Organophosphate
METAFORT	Organophosphate
NUVOS	Organophosphate
ORTHENE	Organophosphate
PERMEX	Pyrethroid
PIRIMOR	Carbamate
RENEGADE INSECTICIDE	Pyrethroid
RIPCORD PLUS	Pyrethroid
STRIKE OUT	Pyrethroid
THIMET	Organophosphate

For more information about a specific product refer to the product packaging or the MSDS safety sheet for the chemical.

13. Reference List

References

Adewole, A. "Risk factors associated with outbreak of methanol poisoning in southern districts of Ondo State Nigeria, May 2015." International Journal of Infectious Diseases 45 (2016): 328.

Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for Copper. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. (2004)

Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for Lead. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. (2007)

Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for Toluene. (Draft for Public Comment). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. (2015)

Ahmed, Farid E. "Toxicology and human health effects following exposure to oxygenated or reformulated gasoline." Toxicology letters 123.2 (2001): 89-113.

Arévalo-Silva, Carlos, *et al.* "Ingestion of caustic substances: a 15-year experience." The Laryngoscope 116.8 (2006): 1422-1426.

Awasthi, Gyanendra, *et al.* "Epidemiological studies on Petroleum toxicity." (2016).

Ballantyne, Bryan, and Timothy C. Marrs. *Clinical and experimental toxicology of organophosphates and carbamates*. Elsevier, 2013.

Barceloux, Donald G., *et al.* "American Academy of Clinical Toxicology Practice Guidelines on the Treatment of Ethylene Glycol Poisoning. Ad Hoc Committee." Journal of toxicology. Clinical toxicology 37.5 (1998): 537-560.

Bardin, Philip G., et al. "Organophosphate and carbamate poisoning." *Archives of internal medicine* 154.13 (1994): 1433-1441.

Benachour, Nora, and Gilles-Eric Séralini. "Glyphosate formulations induce apoptosis and necrosis in human umbilical, embryonic, and placental cells." Chemical research in toxicology 22.1 (2008): 97-105.

Bingham, Eula, Ruth P. Trosset, and David Warshawsky. "Carcinogenic potential of petroleum hydrocarbons: a critical review of the literature." Journal of environmental pathology and toxicology 3.1-2 (1979): 483.

Bongardt, Frank, *et al*. "Fuel additives." U.S. Patent No. 7,172,635. 6 Feb. 2007.

Bradberry, Sally M., Alex T. Proudfoot, and J. Allister Vale. "Glyphosate poisoning." Toxicological reviews 23.3 (2004): 159-167.

Burns, Kathleen M., and Ronald L. Melnick. "MTBE: recent carcinogenicity studies." International journal of occupational and environmental health 18.1 (2012): 66-68.

Caltex MSDS Unleaded Petrol https://caltex.co.nz/assets/Product-and-Services/Products-and-Services/MSDS/Caltex-Petrol-Unleaded.pdf 2015

Campbell, William C. "Ivermectin, an antiparasitic agent." Medicinal research reviews 13.1 (1993): 61-79.

Canadian Centre for Occupational Health and Safety https://www.ccohs.ca/oshanswers/chemicals/chem_profiles/sodium_hydroxide.html 2017

Caprino, Luciano, and Giuseppina I. Togna. "Potential health effects of gasoline and its constituents: A review of current literature (1990-1997) on toxicological data." Environmental Health Perspectives 106.3 (1998): 115.

Center for Disease Control https://emergency.cdc.gov/agent/chlorine/basics/facts.asp 2013

Chung, Eun Hee. "Vaccine allergies." Clinical and experimental vaccine research 3.1 (2014): 50-57.

Chuttani, H. K., *et al.* "Acute copper sulfate poisoning." The American journal of medicine 39.5 (1965): 849-854.

Cobb, Nathaniel, and Ruth A. Etzel. "Unintentional carbon monoxide—Related deaths in the United States, 1979 through 1988." Jama 266.5 (1991): 659-663.

Cotreau, Monette M., *et al.* "The antiparasitic moxidectin: safety, tolerability, and pharmacokinetics in humans." The Journal of Clinical Pharmacology43.10 (2003): 1108-1115.

Cox, Robert D., and William J. Phillips. "Ethylene glycol toxicity." Military medicine 169.8 (2004).

Das, Rupali, and Paul D. Blanc. "Chlorine gas exposure and the lung: a review." Toxicology and industrial health 9.3 (1993): 439-455.

Emoto, Yuko, *et al.* "Autopsy results of a case of ingestion of sodium hydroxide solution." Journal of toxicologic pathology 29.1 (2015): 45-47.

Eskenazi, Brenda, Asa Bradman, and Rosemary Castorina. "Exposures of children to organophosphate pesticides and their potential adverse health effects." *Environmental health perspectives* 107.Suppl 3 (1999): 409.
Fagin, James, Julian Bradley, and Derek Williams. "Carbon monoxide poisoning secondary to inhaling methylene chloride." British medical journal281.6253 (1980): 1461.
Friedman, Perry, *et al*. "Carbon monoxide exposure during pregnancy." Obstetrical & gynecological survey 70.11 (2015): 705-712.
Gaetke, Lisa M., Hannah S. Chow-Johnson, and Ching K. Chow. "Copper: toxicological relevance and mechanisms." Archives of toxicology 88.11 (2014): 1929-1938.
Garg, Jalaj, *et al.* "Cardiovascular Abnormalities in Carbon Monoxide Poisoning." American journal of therapeutics (2014).
Gasnier, Céline, *et al.* "Glyphosate-based herbicides are toxic and endocrine disruptors in human cell lines." Toxicology 262.3 (2009): 184-191.
Grandjean, Philippe, and Philip J. Landrigan. "Neurobehavioural effects of developmental toxicity." The Lancet Neurology 13.3 (2014): 330-338.
Henderson, A. M.; Gervais, J. A.; Luukinen, B.; Buhl, K.; Stone, D. 2010. Glyphosate General Fact Sheet; National Pesticide Information Center, Oregon State University Extension Services. http://npic.orst.edu/factsheets/glyphogen.html.
Husak, Viktor. "Copper and copper-containing pesticides: Metabolism, toxicity and oxidative stress." Journal of Vasyl Stefanyk Precarpathian National University 2.1 (2015): 38-50.
IARC Monograph, Copper http://monographs.iarc.fr/ENG/Classification/latest_classif.php (1989)
IARC Monograph, Glyphosate https://www.iarc.fr/en/media-centre/iarcnews/2016/glyphosate_IARC2016.php (2016)
King, Andrew M., and Cynthia K. Aaron. "Organophosphate and carbamate poisoning." *Emergency medicine clinics of North America* 33.1 (2015): 133-151.
Kumar, Vijay, *et al.* "A study of dose response and organ susceptibility of copper toxicity in a rat model." Journal of Trace Elements in Medicine and Biology 29 (2015): 269-274.
Laidlaw, Mark AS, *et al*. "Case studies and evidence-based approaches to addressing urban soil lead contamination." Applied Geochemistry (2017).
Leth, Peter Mygind, and Markil Gregersen. "Ethylene glycol poisoning." Forensic science international 155.2 (2005): 179-184.
Liu, Shenghua, et al. "Study of spark ignition engine fueled with methanol/gasoline fuel blends." *Applied Thermal Engineering* 27.11 (2007): 1904-1910.
National Center for Biotechnology Information. PubChem Compound Database; CID=241, https://pubchem.ncbi.nlm.nih.gov/compound/241 (2017).
Marrs, Timothy C. "Organophosphate poisoning." *Pharmacology & therapeutics* 58.1 (1993): 51-66.
Mason, Lisa H., Jordan P. Harp, and Dong Y. Han. "Pb neurotoxicity: neuropsychological effects of lead toxicity." BioMed research international2014 (2014).
McDonald, T. O., *et al*. "Acute ocular toxicity of ethylene oxide, ethylene glycol, and ethylene chlorohydrin." Bulletin of the Parenteral Drug Association27.4 (1972): 153-164.
McDowell, Rebecca, Jeff Fowles, and David Phillips. "Deaths from poisoning in New Zealand: 2001-2002." The New Zealand Medical Journal (Online)118.1225 (2005).
McMartin, Kenneth, Dag Jacobsen, and Knut Erik Hovda. "Antidotes for poisoning by alcohols that form toxic metabolites." British journal of clinical pharmacology (2016).
McMartin, Kenneth, Dag Jacobsen, and Knut Erik Hovda. "Antidotes for poisoning by alcohols that form toxic metabolites." British journal of clinical pharmacology (2016).
Meeusen, Els NT, *et al.* "Current status of veterinary vaccines." Clinical microbiology reviews 20.3 (2007): 489-510.
Mennear, John H. "Carcinogenicity studies on MTBE: Critical review and interpretation." Risk analysis 17.6 (1997): 673-681.
Mesnage, Robin, Bernoit Bernay, and G-E. Séralini. "Ethoxylated adjuvants of glyphosate-based herbicides are active principles of human cell toxicity." Toxicology 313.2 (2013): 122-128.
Mesnage, Robin, *et al*. "Major pesticides are more toxic to human cells than their declared active principles." BioMed research international 2014 (2014).
Ministry of Health http://www.health.govt.nz/your-health/conditions-and-treatments/diseases-and-illnesses/tetanus 2014
Ministry of Health http://www.health.govt.nz/your-health/healthy-living/environmental-health/hazardous-substances/removing-lead-based-paint 2016
Newsweek http://www.newsweek.com/glyphosate-now-most-used-agricultural-chemical-ever-422419 2016
Pohanka, Miroslav. "Toxicology and the biological role of methanol and ethanol: Current view." Biomedical papers 160.1 (2016): 54-63.

Poisons Information Centre Database (Toxinz.com) “Campyvax Poison Information Monograph” (2017)
Ramasamy, Kovil, and Vivek V. Gumaste. "Corrosive ingestion in adults." Journal of clinical gastroenterology 37.2 (2003): 119-124.
Ray, David E., David Ray, and Philip J. Forshaw. "Pyrethroid insecticides: poisoning syndromes, synergies, and therapy." *Journal of Toxicology: Clinical Toxicology* 38.2 (2000): 95-101.
Remor, Aline Pértile, *et al*. "Occupational exposure of farm workers to pesticides: biochemical parameters and evaluation of genotoxicity." Environment International 35.2 (2009): 273-278.
Richard, Sophie, *et al.* "Differential effects of glyphosate and roundup on human placental cells and aromatase." Environmental health perspectives(2005): 716-720.
Rose, Jason J., *et al.* "Carbon monoxide poisoning: pathogenesis, management, and future directions of therapy." American journal of respiratory and critical care medicine 195.5 (2017): 596-606.
Rozman, Karl K., and Curtis D. Klaassen. "Casarett and Doull’s toxicology: the basic science of poisons." (2007): 107-132.
Sabin, Robert. "Potentiation of fixed coppers and other pesticides containing copper and supplementing plant nutrition." U.S. Patent No. 9,247,734. 2 Feb. 2016.
Schwartz, Joel. "Low-level lead exposure and children′ s IQ: a metaanalysis and search for a threshold." Environmental research 65.1 (1994): 42-55.
Scott, Daniel A. "Vaccines against Campylobacter jejuni." Journal of Infectious Diseases 176.Supplement 2 (1997): S183-S188.
Speight, James G. "Total Petroleum Hydrocarbons." Environmental Analysis and Technology for the Refining Industry, Volume 168 (2005): 207-235.
Spickler, Anna R., and James A. Roth. "Adjuvants in veterinary vaccines: modes of action and adverse effects." Journal of Veterinary Internal Medicine17.3 (2003): 273-281.
Tephly, Thomas R. "The toxicity of methanol." *Life sciences* 48.11 (1991): 1031-1041.
Tormoehlen, L. M., K. J. Tekulve, and K. A. Nanagas. "Hydrocarbon toxicity: a review." Clinical toxicology 52.5 (2014): 479-489.
U.S. National Library of Medicine https://medlineplus.gov/ency/article/002751.htm 2015
US EPA Cancer Assessment Copper https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=368
Vijverberg, Henk PM, and Joep vanden Bercken. "Neurotoxicological effects and the mode of action of pyrethroid insecticides." *Critical reviews in toxicology* 21.2 (1990): 105-126.
Wildemann, Tanja M., Steven D. Siciliano, and Lynn P. Weber. "The mechanisms associated with the development of hypertension after exposure to lead, mercury species or their mixtures differs with the metal and the mixture ratio." Toxicology 339 (2016): 1-8.
Williams, Gary M., Robert Kroes, and Ian C. Munro. "Safety evaluation and risk assessment of the herbicide Roundup and its active ingredient, glyphosate, for humans." Regulatory Toxicology and Pharmacology 31.2 (2000): 117-165.
Winder, Chris. "The toxicology of chlorine." Environmental research 85.2 (2001): 105-114.
Worksafe NZ http://www.worksafe.govt.nz/worksafe/information-guidance/all-guidance-items/carbon-monoxide-factsheet-invisible-and-deadly (2017)
Yardley-Jones, Anderson, D. Anderson, and D. V. Parke. "The toxicity of benzene and its metabolism and molecular pathology in human risk assessment." British journal of industrial medicine 48.7 (1991): 437-444.

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