

**Retrospective Analysis of Suspected Pesticide-Related Fatalities Admitted to  
Salt River Mortuary in the West Metropole of Cape Town, Republic of South  
Africa.**

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## **Abstract**

**Introduction:** Pesticides offer great benefits in the agricultural sector, but exposure may pose both acute and chronic health risks to humans. In developing countries, morbidity and mortality rates related to pesticide exposure are high and in certain areas (such as in rural, lower socio-economic and/or agricultural-dependent communities), pesticides may be stored in and around homes, which may increase the risk of accidental exposure as well as intentional poisoning. In Cape Town, South Africa, this public health issue is exacerbated by the informal selling of *street pesticides*. These are pesticides that usually comprise of a mixture of these chemicals, sold unregistered as liquids or granules in bottles or packages without clear identification labels, for domestic use. While cheap and widely available in informal settlements; these pesticide formulations are not regulated and extremely toxic. Data illustrating the extent and nature of fatalities related to acute and chronic pesticide exposure in Cape Town, particularly as related to *street pesticides*, is limited. This dissertation provides an overview of the literature associated with pesticide toxicity and related mortality, paying particular attention to available South African research. This is followed by a study investigating pesticide deaths at Salt-River Mortuary over a period of five years.

**Aim:** The aim of this study was to determine the prevalence and characteristics of deaths associated with suspected acute pesticide toxicity, to broaden the spectrum of knowledge concerning pesticide-related deaths in Cape Town, South Africa.

**Methods:** A retrospective analysis of cases admitted to Salt River Mortuary (SRM) from 2011 to 2015 (inclusive) was conducted. Demographic, autopsy, investigative and toxicological data (where available) were collected from post-mortem and other investigative reports.

**Results:** Of the total of 16,453 cases admitted to SRM over a five-year period from January 2011 until December 2015, 104 (0.63%) were deemed to be acutely pesticide-related based on available autopsy data. There was an equal number of male (n=52; 50%) and female (n=52; 50%) victims. Most deaths (n=74; 71%) occurred at medical centres following exposure, and Terbufos was found to be the common pesticide detected analytically (n=42, 61%) in toxicology reports available (76%). Results revealed that (60%) of acute pesticide toxicity cases were suspected suicides, while (6%) of cases were suspected accidents and (3%) cases

were suspected homicides, while the remainder were still undetermined pending toxicological investigations.

**Conclusion:** A history of ingestion, autopsy findings and toxicological results (if available) assisted in identification of these cases, most of which came from lower socio-economic communities. While the number of overall cases is low, it is evident that these deaths are a public health burden, and may be preventable through improved notification and policy development. Challenges with this study involved the inability to distinguish mortality associated with chronic pesticide exposure, the lack of toxicological results available, limited scene investigation information to identify street pesticide contributions, and that the study was limited to one mortuary in Western Cape. An extension of this research to other mortuaries in Western Cape as well as collaborative work with community and public health sectors on availability and toxicity of street pesticides will assist in strategic intervention methods and policy reform to reduce accidental and suicidal mortality associated with acute pesticide exposure.

*Key words: Acute pesticide toxicity, Organophosphates, Post-mortem toxicology, Cape Town, Street Pesticides, South Africa*

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## Abbreviations

ACh	Acetylcholine
AChE	Acetylcholinesterase
DAFF	Department of Agriculture, Forest and Fishery
DOA	Dead on arrival
EDP	Endocrine Disrupting Properties
EDTA	Ethylenediaminetetraacetic acid
GC/MS	Gas chromatography mass spectrometry
LC/MS	Liquid chromatography mass spectrometry
NADP	Nicotinamide adenine dinucleotide phosphate
NADPH	Nicotinamide adenine dinucleotide
OP	Organophosphates
OPC	Organophosphate Chemicals
PM	Post-Mortem
POP	Persistent Organic Pollutants
RSA	Republic of South Africa
SPE	Solid phase extraction
SRM	Salt River Mortuary
TLC	Thin Layer Chromatography
WC	Western Cape
WHO	World Health Organisation
WTO	World Trade Organisatio



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# **Chapter 1 – Literature review**

## **Chapter 1 – Literature Review**

### **1. Introduction**

Pesticides offer obvious benefits in agriculture, but exposure to these chemicals may pose risks to humans (Abdullat et al, 2006). The term pesticide refers to herbicides, fungicides and insecticides, amongst others, which are all used to control pests. Pests in turn, are defined as undesired living organisms, which may cause damage to plants, humans and/or other animals and include insects, rodents (amongst other scavenging animals), plants, fungi and microorganisms (Ziya et al, 2013). Pesticides have been classified by the World Health Organisation according to their level of toxicity from Class 1a (extremely hazardous) to Class 3 (slightly hazardous) (Ziya et al, 2013).

Pesticides are produced and used world-wide for agricultural benefits but in turn they also cause harm especially in developing countries, where the use thereof is elevated (Peshin et al, 2014). The agricultural (and domestic) benefits of pesticides in comparison to their toxicity and effect on human health, should be weighed against each other and ultimately the replacement of pesticides with less toxic but still effective alternatives should strongly be considered (Eddleston et al, 2002). Previous studies have found, for example, that stable crop production with reduced pesticide use is possible (Eddleston et al, 2002). In developing countries, morbidity and mortality rates related to pesticide exposure are high, as reported by the World Health Organisation (WHO) (Peshin et al, 2014). In certain areas, such as in informal settlement and poorer communities, pesticides are stored in and around homes (Peshin et al, 2014), which may increase the risk of accidental exposure as well as intentional poisoning.

Pesticide-related fatalities may be under reported and information concerning these poisonings is lacking internationally and particularly in South Africa. A short overview of literature regarding pesticides poisonings, fatalities, clinical and post-mortem findings in these cases will be discussed as an introduction to the retrospective study subsequently presented and discussed. This retrospective review focuses on pesticide-related deaths in admitted to Salt River Mortuary in Cape Town, South Africa over a five year period (January 2011- December 2015), with the aim of broadening the knowledge gap relating to pesticide-related fatalities and their health burden to the country.

## 2. Pesticides

### 2.1 Applications

Poisoning due to exposure to pesticides is a worrying health harm, especially given the reported unprotected usage thereof by farmers in the field (Stokes et al, 1995; Smith et al, 2003). This type of exposure can occur during the mixing, loading and application of pesticide chemicals. In addition to the direct use and contact with pesticides, many other people can be affected due to pesticide drift from sprayed fields if they live in close proximity to these fields, inappropriate storage of pesticides, or access to contaminated equipment (Azaroff and Neas, 1999). In addition, pesticide residues, often invisible to the naked eye, may contaminate domestic environments and people who come into contact with the pesticide itself or others who may have used the pesticides. Even if poisoning as such is not the result of indirect exposure, toxic exposure of residues may lead to a variety of illnesses.

### 2.2 Types of pesticides

Pesticides are usually classified according to their functions. The most common pesticides are herbicides (kill weeds), insecticides (kill insects), fungicides (kill fungi), and bactericides (kill bacteria). Other types of pesticides include: disinfectants (destroys microorganisms), defoliants (removes leaves), desiccants (fast drying of plants), and repellents (repels various creatures e.g. mites, ticks etc.). Pesticides may also be classified according to their toxicity as reported by WHO (The WHO Recommended Classification of Pesticides by Hazard, 2009)

**Table 1:** WHO Classification of pesticides according to their toxicity.

<i>Classification</i>		<i>Examples of Pesticides</i>
<b>Ia</b>	Extremely hazardous	Aldicarb, Mevinphos, Parathion
<b>Ib</b>	Highly hazardous	Dichlorvos, Carbofuran, Chlorfenvinphos
<b>II</b>	Moderately hazardous	Carbosulfan, Diazinon, Endosulfan
<b>III</b>	Slightly hazardous	Glyphosate, Malathion, Atrazine
<b>U</b>	Unlikely to present acute hazard	Amitrole, Zineb, Cinosulfuron

### 2.3 Regulations in South Africa

In South Africa, pesticide legislation dates back to 1947 (Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies, Act No. 36 of 1947). This legislation is not only out of date, but the enforcement and pesticide surveillance thereof is poor. In addition, it allows anyone to purchase and use agricultural pesticides (Rother, 2010). It requires the reporting of poisoning with any pesticide as listed in the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies, 1947 (Act No. 36 of 1947), to the Department of Health. In reality, this is not always performed or reporting is inaccurate. For example, poisonings occurring from organophosphate-containing pesticides may commonly be reported from clinical symptomology patterns, yet the specific pesticide and/or whether it is in fact another pesticide such as a carbamate, is not always known or reported. This violates legislation and leads to the under reporting of pesticide poisoning (Rother, 2012). Pesticides are not routinely considered when making a diagnosis of those presenting to health care institutions. Adequate training in this regard, to those in the healthcare sector is of paramount importance, as many patients from urban and non-agricultural areas may be misdiagnosed especially as symptoms of pesticide-related poisoning closely resembles symptoms of flu (Rother, 2012).

The Department of Agriculture, Forest and Fisheries (DAFF) is the responsible body for the registration and regulation of pesticides in the Republic of South Africa (RSA). Currently the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies, 1947 (No. 36 of 1947) is limited in pesticide regulatory actions and these pitfalls have been recognized and amended in the DAFF Notice 1120 of 2010: "Pesticide Management Policy for South Africa", to provide information as a guideline to support pesticide legislation and regulations. The policy recognises that the use of certain pesticides, posing unmanageable risks, has to be prevented. These include pesticides that have endocrine disrupting properties (EDP), and are Persistent Organic Pollutants (POPs) eg: polychlorinated biphenyls, those with carcinogenic and immunotoxic potential and pesticides that are classified as Class 1a and Class 1b by the WHO, as well as those that are most frequently identified in poisonings. (DAFF Notice 1120 of 2010: "Pesticide Management Policy for South Africa") The DAFF furthermore recommend the application of pesticide reduction strategies to all its activities, as well as the registration of pesticides. Identification and use of alternative products with similar functions but lower toxicity is also suggested, together with a review of existing pesticides. The policy recognises

that the 1947 Act described above is out-dated, and that provision is to be made for the revision thereof.

The Pesticide Management Policy in short aims to improve the legislative framework, and increase protection regarding health and environmental risks of pesticides. This includes encouragement of the use of alternative products and methods, and increasing transparency, availability of information and the improvement of participation amongst the public in the registration process of pesticides. It is clear however, that objectives are only obtainable through joint efforts between government, the agro-chemical industry, farmers, community-based and non-governmental organisations, as well as consumers and stakeholders. The use of agricultural pesticides for domestic purposes is however an unregulated challenge, and pesticide legislation and management in this regard is failing (Rother, 2010).

### **2.3.1 Street pesticides**

*Street pesticides* are usually made from agricultural pesticides, and sold in unregistered and unlabelled containers in the informal settlements for domestic use (Balme *et al.*, 2010; Rother, 2010). In Cape Town, *street pesticides* are widely and cheaply available, but given their high toxicity, increasing the risks of human poisoning (Rother, 2010). Although the prevalence of street pesticides is unknown in South Africa, a study conducted in Cape Town revealed that youth are mostly vulnerable to exposure from these street pesticides, as they are involved in the selling and distribution thereof (Rother, 2010). Furthermore youth are affected more adversely than adults when exposed to these products and documented health effects of these exposures include: asthma, neurological effects, hormone disruption and cancer amongst others (Rother, 2010). Exposure to these pesticides is increased during the handling, transport and packaging of products. For example, there is an increased possibility of spillage, particularly when decanting liquid pesticides in smaller containers for distribution (Balme *et al.*, 2010). These products are also widely available, being sold at taxi ranks, train stations and on the streets (Rother, 2012). Despite the suggested pervasive nature of these products, very limited analytical data is available on their specific composition.

Some studies have identified a few compounds in these products, one being aldicarb, that is extremely hazardous and listed as a Class 1a pesticide by the WHO (Balme *et al.*, 2010). Another exploratory study based on this framework showed that highly-toxic pesticides, such



as aldicarb, chlorpyrifos, chlorpyrifos-methyl, methamidophos and cypermethrin were easily available in as *street pesticides* in the informal markets in Cape Town's urban periphery (Rother, 2010). Agricultural pesticides consists of a higher concentration of active ingredients and are generally more toxic than pesticides approved for domestic use, and therefore the effects of these illegally used *street pesticides*, can range from short-term acute health problems to long-term chronic effects (Rother, 2010).

However, use of these products is a complex and systemic issue. Inadequate pest management strategies, demand, supply and joblessness all contribute towards the selling and distribution of street pesticides (Rother, 2010). The South African government has failed to address and assist the poor pest invaded areas as well as improve the regulation of the illegal products. In addition, those involved in the selling and distribution of these products do not have access to material data safety sheets of these products and are therefore not educated with regard to the risk and dangers thereof (Rother, 2010). However even if vendors of street pesticides had access to this information it is improbable that they would apply these safety measures. An effective surveillance program is yet to be implemented in RSA to combat the exposure to pesticides, particularly street pesticides (Rother, 2012). Although pesticide use in RSA is extensive, it remains a low public health concern. The lack of surveillance and possible misdiagnosis of pesticide poisonings all contribute to the lack of data concerning pesticide related poisoning in RSA (Rother, 2012).

### **3. Pesticide Types, Toxicity and Poisonings**

#### **3.1 General**

Pesticide poisoning has become an important health issue worldwide, and the WHO reports that approximately 3 million severe pesticide poisonings are reported annually, approximately 220 000 thereof are fatal, and approximately 25 million symptomatic occupational poisonings have occurred amongst agricultural workers (Jeyaratnam, 1990). High exposure to pesticides is reported to occur in developing countries, such as in Costa Rica for example, where usage was estimated to be eight times higher than the 0.5kg estimated for the whole world population, with as much as 4 kg of pesticides being used per capita in the country (WHO, 1990; Wesseling & Trivelato, 1990). A lack of epidemiological surveillance systems exist in low income areas and not enough is known with regards to the health impact

of pesticides (Wesseling *et al.*, 1993). Although this study was conducted 24 years ago, morbidity and mortality rates continue to rise and the same challenges are present today.

Typically pesticide poisoning occurs in agricultural settings, especially in poor countries due to inadequate safety standards, such as the lack of personal protective equipment, poor washing facilities, poor labelling and deliberate ingestion or administration due to their wide availability (Ziya *et al.*, 2013). In developed countries, various strategies have contributed to the decrease in poisoning cases. Examples of such strategies include: educational prevention programs, as well as child-resistant packaging and product reformulation (Balme *et al.*, 2012). Children and infants may be unintentionally exposed to pesticides, whereas adult exposure may be related to occupation of work or self-harming methods (Balme *et al.*, 2010). In all settings, if pesticide-related death occurs, the manner of death may be in the form of accidental exposure, suicide or even homicide. In certain cases, for example in agricultural workers, chronic exposure to pesticides may lead to the development of natural disease identified at autopsy. In these cases, relating death to chronic pesticide exposure may not be isolated. In addition, identifying the role of specific pesticides in acute on chronic exposure may also be challenging.

Pesticide poisoning has resulted in high rates of morbidity and mortality especially in lower socio-economic regions (Balme *et al.*, 2010). In these areas, overcrowding is common and little dwelling space is available. This may result in the use of *street pesticides* to combat infestations, such as in crowded informal settlements. These products are usually comprised of a mixture of potent ingredients, sold in decanted packaging without clear identification labels as mentioned previously (Balme *et al.*, 2010). Due to the latter, many causes of poisoning cannot be associated with specific pesticides, particularly without analytical confirmation. Furthermore, clinical diagnosis may be unclear or based on witness testimony reporting the ingestion of unknown substances. Akgür *et al.* (2003) found that in most suicide cases involving pesticides, a combination of pesticides were present because suppliers sell their products premixed to increase the product's efficacy. A vast variety of toxic pesticides are available, contributing to increased morbidity and mortality rates when exposed. Diagnosis of pesticide-related poisonings may be challenging due to the similar or otherwise varying effects of different pesticides.

### **3.2 Examples of pesticides and their classes**

An array of pesticides classes exists of which Carbamates, Organophosphates and Paraquat are most commonly known. Their action is largely related to AchE inhibition and clinical signs typically involve visceral congestion, pulmonary oedema, blistering, ulceration and erythema amongst others.

#### **3.2.1 Organophosphates**

Organophosphates (OP) are widely available and most commonly used in comparison to other pesticides (Chowdhary *et al.*, 2014). The WHO has estimated that 3 million individuals suffer from OP poisoning and approximately 250 000 people in Asia (mostly) die from OP poisoning annually. Organophosphates are commonly used for controlling of mosquito plaques as well as sucking and chewing pests. These are highly toxic compounds that have resulted in numerous cases of fatal poisoning in the manner of accidental ingestion, suicide and or homicide (Park *et al.*, 2009). The degree of OP toxicity varies depending on the dose, the route of administration as well as the pharmacodynamic properties of the compound (Chowdhary *et al.*, 2014). Organophosphates inhibit acetyl cholinesterase (AChE) causing phosphorylation of the serine hydroxyl residue on AChE (Ziya *et al.*, 2013). This leads to the accumulation of acetylcholine (ACh) in the body. Nerve function is dependent on ACh and when an irreversible blockage of ACh occurs it results in muscle overstimulation (Ziya *et al.*, 2013). The study conducted by Ziya *et al.* (2013), found that organophosphates were the leading constituents of pesticides resulting in poisoning and death (Ziya *et al.*, 2013).

Treatment for organophosphate poisoning needs to occur as early as possible (Chowdhary *et al.*, 2014). Time elapsed between sample transportation, testing, delivery of reports and enzyme activity is detrimental in OP treatment. Therefore in an emergency setting it is important for diagnosis and treatment to commence immediately (Chowdhary *et al.*, 2014). The gold standard in clinical assessment for OP toxicity is the acetyl cholinesterase assay (erythrocyte cholinesterase assay) (Dasgupta *et al.*, 2007). Prior knowledge of baseline enzyme activity is important when diagnosing especially low cases of pseudocholinesterase levels. (Lessenger & Reese, 1999). Although the Ellman's method for determination of acetyl cholinesterase levels are not complication free, it has been successfully used for decades, for the diagnosis of OP poisoning (Worek *et al.*, 2012). Pseudocholinesterase levels of >50% of

normal (>3500IU/L), 20-50% of normal (>1401-3500IU/L), 10-20% of normal (701-1400IU/L) and <10% (<700IU/L) are deemed to be associated with possible OP poisoning for cases of latent poisoning, mild poisoning, moderate poisoning and severe poisoning respectively (Kumar *et al*, 2012).

Medical care may also include supportive care and immuno-modulatory drugs, although the success with this alone is low (Gawarammana & Buckley, 2011). Management strategies in OP poisoning include the removal of poison from the skin and stomach, depending on the route of exposure, and maintaining ventilation, cardiac rhythms as well as blood pressure (Eddleston *et al.*, 2008 and Jokanović 2009). Specific antidotes like atropine, oximes and benzodiazepines are to be administered as they relieve symptoms as well as assist in the reactivation of inhibited acetyl cholinesterase and the treatment of seizures caused by OP poisoning respectively (Chowdhary *et al.*, 2014). A need for point of care treatment that can be completed close to the patient presenting with symptoms of OP poisoning is suggested by Chowdhary *et al.* (2014), to ensure rapid diagnosis and treatment.

### **3.2.2 Carbofuran**

Carbamates are insecticides that include aldicarb, oxamyl, terbucarb and carbofuran amongst others. Carbofuran (Furadan) is commercially available in a variety of products, e.g.: veterinary and agricultural products. It is a highly toxic insecticide, although it is classed as being less toxic than organophosphates (Ferslew *et al.*, 1992). Like organophosphates, carbofuran inhibits cholinesterase, causing the accumulation of acetylcholine (Ferslew *et al.*, 1992). Toxic manifestations include: diarrhea, urination, miosis, bronchospasm, emesis, lacrimation, salivation, muscle fasciculation and convulsions (Ellenhorn, M.J. & Barceloux, G.G., 1988; Olson, K.R. 1990; Murphy, S.D., 1986). Absorption of carbofuran occurs through inhalation, by ingestion and through the skin (Ellenhorn, M.J. & Barceloux, G.G., 1988; Olson, K.R. 1990; Murphy, S.D., 1986). The clinical signs of carbamate exposure have a shorter duration, when compared to that of organophosphates, due to the reversible carbamylation of cholinesterases in comparison to the irreversible phosphorylated cholinesterases from organophosphates (Ferslew *et al.*, 1992). For diagnostic purposes, blood and plasma acetyl cholinesterase levels are not always helpful due to the transient effects of carbamates (Ellenhorn & Barceloux, 1988 ; Olson, K.R. 1990). Occupational exposure may present with

measurable concentrations of carbofuran in biological fluids, although the inhibition of cholinesterase will not be evident for up to four days, if protective equipment was used (Hussain *et al.*, 1990). Agricultural exposure without the use of protective equipment, however produced typical signs of cholinesterase inhibition (Coleman *et al.*, 1990).

Carbamate poison management include the administration of atropine in small doses to reverse the effects of the toxic substance. Atropine can be administered intravenously or intramuscularly (Roberts and Reigart, 2005). The aim for atropine treatment is to antagonize the effects of the increased acetylcholine build up in end organs due to the presence of muscarinic receptors. The reactivation of AChE does not occur and atropine does not cause the excretion or breakdown of carbamates. Multiple doses of atropine may therefore be required. It is effective if muscarinic manifestations are present but it is ineffective against nicotinic actions (Roberts and Reigart, 2005).

### **3.2.3 Paraquat**

Paraquat is a non-selective herbicide that is used globally. In the United States, its use is regulated and only accessible to trained personnel (Erickson *et al.*, 1997). Unfortunately this is not the case in all countries, where concentrated paraquat is easily accessible and stored in decanted containers that may increase rates of accidental poisoning (Winchester 1995; Greenberg 1995; Mc Mahon 1996).

Paraquat has low environmental toxicity as it becomes deactivated upon contact with soil and it disrupts photosynthesis in plants (Winchester 1995; Vale 1987.). When orally ingested by humans, it is poorly absorbed and causes either an immediate or delayed toxicity that may result in multiple organ damage. The precise mechanism of toxicity in humans has not been clearly demonstrated but involves the conversion of Nicotinamide adenine dinucleotide phosphate (NADP+) to Nicotinamide adenine dinucleotide (NADPH). Cell death ultimately follows due to lipid peroxidases and oxygen free radical formation (Vale, 1987). Results of ingestion include erythema, blistering or ulceration of the oral and gastrointestinal mucosa and a dosage of 3-6g of paraquat is considered lethal to adults (Suzuki *et al.*, 1993; Vale, 1987). In the case of systemic absorption, various outcomes are possible and may include: multiple organ failure, progressive pulmonary fibrosis, acute renal tubular haemorrhage, and ultimately death (Erickson *et al.*, 1997). It has been reported that a direct correlation exists

between the amount of paraquat ingested and the outcome of the effects thereof that includes the possibility of death (Erickson *et al.*, 1997). In the case of paraquat poisoning, early clinical presentation in the lungs, heart, liver and kidneys can result in death due to pulmonary, renal, and circulatory failure or hepatic necrosis. Death may occur due to pulmonary failure, renal failure, circulatory failure or hepatic necrosis (Chen *et al.*, 1994). Other acute toxic affects including burns, ulceration, focal haemorrhage of the gastrointestinal tract and acute tubular necrosis (Dasta, 1987). Survivors of paraquat poisoning have reported chronic toxic effects to the eye, gastro-intestinal tract, pulmonary and renal systems (Bismuth & Hall 1995).

Management and treatment of paraquat poisoning includes the immediate administration of fluids to ensure urine output and the decontamination of the gut (Erickson *et al.*, 1997). Decontamination of the gut can be achieved by administration of Fuller's earth, activated charcoal or bentonite suspension, and is considered to be the most critical step (Dasta, 1987; Meredith & Vale, 1995). Haemodialysis or haemoperfusion should commence and antidotes should be administered, e.g.: antioxidants, acetyl cysteine, deferoxamine or anti-paraquat antibodies. It is also critical that airway ventilation is maintained by using a low oxygen level as opposed to a high flow oxygen level, to limit further pulmonary complications (Erickson *et al.*, 1997). Physicians should include paraquat poisoning as a potential cause when diagnosing patients presenting with pulmonary, gastro-intestinal tract and renal symptoms together with a history of pesticide ingestion (Erickson *et al.*, 1997).

### **3.3 Pesticide Poisonings and Death**

There is currently limited available data and research concerning the prevalence and characteristics of pesticide poisonings. It has been suggested that by restricting or eliminating access to the most commonly used suicide methods or agents, fatalities may be prevented (Clarke and Lester, 1989). If we identify the characteristics of these fatalities and the substances that cause them, it will assist in both the medico-legal process and possibly aid in reducing pesticide-related fatalities through public health initiatives. For example, the WHO initiated a global public health strategy to decrease morbidity and mortality of pesticide poisoning through policy regulation, surveillance monitoring in clinical and community settings, education on the safe handling, identification and management of pesticides, as well as the development of community programs aimed at minimising risks of exposure (Bertolote

*et al.*, 2006). Internationally pesticide poisoning is reported but this is more so from developed countries with effective reporting processes.

### **3.3.1 International Data**

Pesticides pose a greater risk in developing countries when compared to developed countries, which is compounded by the lack of sufficient regulatory systems, lack of pesticide labelling, limited education in some communities, as well as a lack of personal protective equipment in handling pesticides because of the costs involved (WHO, 2004a). In some instances where protective clothing is available, farmers are reluctant to wear it due to it being uncomfortable and hot, especially in tropical climates (Recena *et al.*, 2006). Another reported reason for higher pesticide poisoning rates in developing countries is the use of the more toxic pesticides at a large scale by small farmers, as these compounds are often more affordable (WHO, 2002, 2004a). A survey conducted in Asia, indicated that as many as 25 million of agricultural workers suffer from an event of pesticide poisoning annually (WHO, 1990). Brazil ranks as the third largest consumer of pesticides globally, with more than 300 million tons of pesticides used in 2001, and over 5000 cases of poisonings reported in the agricultural sector (SINITOX, 2004). Between 1997 and 2001, the majority of reported poisonings were credited to medical drugs, with death due to reported pesticide exposure ranking second following poisoning (SINITOX, 2004).

The study conducted by Recena *et al.*, (2006) over a 10 year period (1992-2002) in Brazil, investigated reported cases of agricultural pesticide poisoning in humans (Recena *et al.*, 2006). Investigation focused on the characterization of the individuals, the circumstances of poisoning as well as the pesticides implicated. Additionally, the primary locations in the state where risk of toxicity was higher were identified (Recena *et al.*, 2006). Data was collected from the Center of Toxicological Vigilance, the National System of Toxic-Pharmacological Information and the Brazilian Institute of Geography and Statistics. Exposure to pesticides, whether voluntarily or involuntarily, was identified in 1355 cases in the Mato Grosso Du Sol (MS) area in Brazil, and occurred over the 10 year period studied averaging at 123,2 poisonings/year. Voluntary exposure accounted for 506 cases and of these, 139 (27, 5%) resulted in death. Fatalities dues to involuntary poisonings accounted for 37 deaths. In a 2 year period (1999 and 2000), 6,9% pesticide poisonings occurred due to pesticides in the

state, amounting to 1371 and 1511 cases respectively of all poisonings in the state. In MS reported cases indicated that, mostly men (55.1%) were exposed to pesticides with their age ranging from 15 years – 49 years. This may reflect the principal work force in the country. It was found that children from the age of 5 years to 14 years old (6.6% of cases) were exposed, possibly during labour as well (Recena *et al.*, 2006). The Brazilian Institute of Geography and Statistics reported that 58% of children between the ages of 5 – 14 years old, living in agricultural areas in the country, during the time period of 2001 were involved in agricultural activities (IBGE, 2004). Children may play close to pesticide treated fields or even follow their parents while they are spraying fields with pesticides (WHO, 2004b).

Pesticides played a role in intentional poisonings in various countries like Brazil for example, where it was the second most common substance used (SINITOX, 2004). In India, intentional pesticide poisoning contributed to 30% of all suicide cases (WHO, 2004a). Similarly pesticides accounted for 71% of pesticide poisonings in Sri Lanka between 1980-1989, and in China 62% of cases was due to pesticide poisoning from 1998-2000 (WHO, 2004a).

In the study conducted by Recena, *et al.*, 2006, agricultural pesticide poisoning rates illustrated to be the highest in 1995 with 65.7 / 100 000 and the lowest in 1996 and 1997, where no poisoning were reported for 5 consecutive months. This may be due to a disruption of the information system or no poisonings occurred (Recena *et al.*, 2006).

After June 2001, it became mandatory to report pesticide poisoning in the state of Mato Grosso do Sul in Brazil, but surprisingly reported poisoning rates decreased by 26.3% from 2000-2002, and in the year 2000, a total of 5127 pesticide poisonings were reported in Brazil (19.4/100 000 people living in rural areas), and this was lower than the incidence rates for the same year in MS which was 34.2/100 000 (Recena *et al.*, 2006).

Underreporting is estimated by Brazil's Ministry of Health to be 50 underreported incidents, to every 1 reported incident (Recena *et al.*, 2006). Reasons for underreporting in Brazil include the lack of access to the medical care and failure to report the illness to the medical system, the failure of health care professionals to identify pesticide poisoning due to symptoms resembling other health problems or illnesses (Recena *et al.*, 2006). Even with the mandatory requirements reporting and recording of the causes of poisoning in hospitals and the information system from hospital to the center of toxicological vigilances, does not always



occur (Recena *et al.*, 2006). It is suggested that South Africa may face similar problems in underreporting.

### **3.3.2 South Africa and Pesticide Poisoning**

A retrospective review conducted by Balme *et al* (2012), found that lower income areas have higher pesticide poisoning cases than adjacent geographical areas in Cape Town with higher income ratios. The study was conducted at the Red Cross War Memorial Children's Hospital (RCWMCH) in Cape Town, South Africa, and involved a review of the hospital records from January 2003 to December 2008, of children that were exposed to toxins or poisons. Data for the study was extracted from the Clinical Poisoning Database and included the following: age, address, season, duration of hospital stay, causative agent, route of exposure, clinical severity and outcome (Balme *et al.*, 2012). Reported results included 2,872 incidents of toxic exposure, with the majority (88%) of the patients being less than 6 years old and more than half (55%) being male. In 90% (n=2,577) of the cases, oral ingestion was the route of exposure. Of these, 60 (2%) were non-accidental, and 50 (2%) were suicide attempts.

Of the total cases (n=2,872), 2853 toxins were involved, with the chief toxin groups being paraffin, drugs, household cleaning products and pesticides. In the majority of cases (n=2,656, 92%), a single toxin was identified and in the remaining cases (n= 85, 3%), two or more toxins were involved. These results had relatively little fluctuation between 2003 and 2008, reaching a peak during the summer months of October to February (Balme *et al.*, 2012). The cause of toxicity varied geographically and in predominantly lower socio-economic areas. Khayelitha, Philippi, Gugulethu, Nyanga and Langa yielded (n=186, 60%) pesticide incidents. The above mentioned areas are primarily dominated by the Black African residents living in informal housing. Mitchell's Plain, Athlone, Manenberg, Hanover Park and Bonteheuwel being adjacent geographical areas to the latter, had a lower incident rate of (n=46, 15%) for pesticides (Balme *et al.*, 2012). These areas have formal housing and are predominantly occupied by the Coloured population.

Organophosphates and carbamates were identified to have caused toxicity 203 (65%) of all pesticide incidents (n=311, 11%) relating to poisoning (Balme *et al.*, 2012). A total of 6 deaths, in this study, were deemed to have resulted from pesticide poisoning, the analytical confirmation of which is limited. This study provides valuable information regarding poisoning

cases in Cape Town, and indicates that very few cases may actually result in death from pesticides if quickly and appropriately treated in hospital.

#### **4. Post-mortem Investigations**

Reports suggest that pesticide exposure result in high mortality, particularly in developing countries (Peshin *et al.*, 2014), however data on fatalities is limited. Presentation of these fatalities may vary depending on the pesticide and route of administration.

In a case report by Ferslew *et al* (1992), a 26 year old white male with a history of insecticide ingestion, died and clinical symptoms included visceral congestion and pulmonary oedema (Ferslew *et al.*, 1992). Mild hepatic steatosis, and anomalous origin of the left common carotid artery from the brachiocephalic trunk was observed. Biological fluids analysed were blood, vitreous humor, bile, urine and gastric contents. The results yielded positive for the detection of carbofuran in the blood as well as the gastric content and substantial cholinesterase inhibition occurred. Plasma, serum, and whole blood cholinesterase activities were greatly inhibited. In vitreous humor and bile, the cholinesterase activity was inhibited by 87% and 74% respectively in comparison to control data (Ferslew *et al.*, 1992). These decreased inhibition ratios in vitreous humor and bile can be due to carbamates not easily crossing the cellular barriers (Ferslew *et al.*, 1992). Ultimately pathological and toxicological results determined the cause of death as anoxia, due to respiratory paralysis caused by carbofuran ingestion. Carbamates do not readily cross the blood brain barrier either and therefore has little effect on the brain and central nervous system cholinesterase activity due its transient effects at low levels (Ellenhorn, M.J. & Barceloux, G.G., 1988; Olson, K.R. 1990; Murphy, S.D., 1986).

An eleven year retrospective case review conducted in Turkey identified 622 cases of fatal poisoning (6% of deaths), of which 70 were attributed to pesticide poisoning (Ziya *et al.*, 2013). Organophosphate-based insecticides were most frequently detected in these cases (64% of pesticide poisoning cases). Pathological findings in cases of pesticide-related poisoning may vary. Findings from a study conducted Ahmad *et al.*, (2014), included cyanosis in the lips nose and fingers, the presence of blood stained froth in the nasal cavity and mouth, and the pungent smell of Organophosphorus Compounds (OPC's) in the stomach content. Congestion of internal organs and oedema was present. Sub-mucosal petechial haemorrhage

in the stomach as well as subpleural petechial haemorrhage was seen (Ahmad *et al.*, 2014). Post-mortem investigation of insecticide deaths as per Mohanty *et al.* (2005) manifested a strong kerosene smell when multiple organophosphorous poisons were involved. In cases with a survival period of longer than three days, no kerosene smell was evident (Mohanty *et al.*, 2005). In the majority of cases reported to survive for 12 hours, a strong kerosene smell was observed (Mohanty *et al.*, 2005). Chemical analysis of the viscera and body fluids yielded positive results for a definite poison within a three day survival period (Mohanty *et al.*, 2005).

In Japan, 1300 deaths occur annually, due to paraquat poisoning (Erickson *et al.*, 1997). In 1991 paraquat was responsible for 75% of the total pesticide deaths in England and Wales (Erickson *et al.*, 1997). In the United States, cases of both accidental as well as intentional paraquat poisoning were reported to emergency departments (Erickson *et al.*, 1997).

A case report on a 71 year old Korean male revealed ingestion of Korean weed killer on the evening of admission as well as 2 days prior (Erickson *et al.*, 1997). His symptoms included a sore throat, difficulty swallowing, congested breathing, nausea, vomiting and diarrhea (Erickson *et al.*, 1997). He experienced moderate distress with increased blood pressure. Further symptoms included midrange pupils, red oropharynx with bright yellow fluid. Congested upper airways were fluid filled and soft tissue oedema and renal failure were present. His family confirmed the case history of organophosphate ingestion (Erickson *et al.*, 1997). The patient died 6 days after admission and serum analysis one day after admission revealed 0.7ug/ml paraquat (Erickson *et al.*, 1997).

#### **4.1 Suicides related to pesticide toxicity**

It is difficult to distinguish between suicides and accidental poisoning (Wesseling *et al.*, 1993). By 1990, the WHO reported that approximately 1 million accidental, and 2 million intentional poisoning with pesticides occur annually worldwide (Recena *et al.*, 2006; Mars *et al.*, 2014). It is also reported that 250 000-370 000 fatalities occur annually from intentional pesticide ingestion resulting in suicidal death (Dawson *et al.*, 2010). The patterns and manner of self-harm and suicide are different in industrialized nations and developing countries (Gunnell and Eddleston, 2003). In the case of poisonings, the differences may be due to the agents or

substances that are predominantly available, as well as the toxicity of these substances. Patterns of poisoning vary due to factors including: accessibility of toxic substances, socio-economic status, religion and culture (Abdullat et al, 2006). This is demonstrated when looking at industrialized countries where access to pesticides is limited due to a small number of farmers in comparison to rural regions of developing countries where more people are working in agriculture and therefore more readily have access to pesticides (Gunnell and Eddleston, 2003). In addition, the regulation and control of more toxic pesticides may be limited in developing countries.

It has been estimated that 3.4 per 100 000 population commit suicide annually in Africa (Mars et al, 2014). The number of pesticide poisoning fatalities is estimated to be much higher in reality, due to the fact that Africa is the largest and second most populated continent in the world and with less than 10% of countries in Africa reporting to the WHO. Moreover, limited data collection and research has been conducted on pesticide toxicity cases leading to death, particularly related to chronic exposure (Mars, et al, 2014). One example includes the hypothesis that there are higher suicide rates in the agricultural sector amongst Brazilian males, which may be due to working in high risk agricultural settings, which is related to high work intensity and long-term exposure to pesticides (Faria *et al.*, 2014). Faria et al. (2014), states that exposure to pesticides creates a predisposition to depression that may increase the risk of committing suicide.

Pesticides are neurotoxic, and the nervous system is a prime target for the acute and chronic effects of many pesticides. Because of this, pesticide exposure has been associated with psychiatric problems that include depression and anxiety which may in turn act as a contributing factor in suicidal behaviour and tendencies (Faria *et al.*, 2014, Freire and Koifman, 2013). However, while some studies have found an association between pesticide exposure and symptoms of depression, other studies have not (Recena *et al.*, 2006), and this is a contentious issue as there are many other factors that may be at play in the particular cases studied. It is therefore not possible to distinguish a causal link between chronic exposure and suicide. However, acute toxicity due to self-ingestion is often observed and can be distinguished as suicidal in nature, given history, scene and circumstantial investigative outcomes. This however may be more challenging in cases of accidental poisoning.

## 4.2 Accidental pesticide fatalities

In 1986, approximately 1800 occupational, accidental pesticide poisonings were reported in Costa Rica (Wesseling *et al.*, 1993). The majority (97%) of these poisonings occurred within the agricultural related working environment, due to occupational pesticide exposure. Approximately 3% of pesticide poisonings, reported toxic events occurring in a non-agricultural working environment. Incidence rates were higher in females across all age groups in comparison to males that displayed higher incidence rates between the ages of 20-29 years (Wesseling *et al.*, 1993). In addition to this the rate of non-occupational poisonings among agricultural workers due to accidental and suicidal poisoning was three times higher than the occurrence thereof amongst the rest of the population (Wesseling *et al.*, 1993).

In a 7 year period, 283 fatalities from pesticide poisoning were autopsied in Costa Rica with more than half being agricultural workers (Wesseling *et al.*, 1993). Furthermore accidental and suicidal death occurred more frequently amongst agricultural workers as well, with the most fatalities between the ages of 15-19 years with no deaths below the age of 15 years, and in any female workers (Wesseling *et al.*, 1993). The fatality rates for females for non-occupational reasons were however higher (60%) in comparison to males (Wesseling *et al.*, 1993).

Poor storage practices resulted in 78% of the non-occupational accidents, as pesticides are confused for food or drink (Wesseling *et al.*, 1993). The use of pesticides as medication to treat lice, intestinal parasites and dermal lesions were also reported (Wesseling *et al.*, 1993). In all fatality cases the causative agents were identified, with paraquat being the principle substance accounting for 60% of all deaths, and caused more deaths compared to other pesticides, irrespective of the manner of poisoning (Wesseling *et al.*, 1993). In developing countries, limited information regarding pesticide poisoning and the populations at risk as well as the circumstances regarding poisoning are available.

In addition, the actual physiological effect of chronic exposure to cells and tissues may also not be attributed to pesticide toxicity at autopsy, but rather natural disease of some form. It is hypothesized that these cases that may be related to chronic pesticide exposure and have direct pathological toxicity are likely to be missed at autopsy as natural pathology may be

attributed to natural disease processes, without contribution from pesticide exposure (as that information is likely not always available or known).

In addition to suicidal and accidental pesticide poisonings homicidal poisonings may also occur although the frequency of occurrence may be much less.

#### **4.3 Homicidal poisoning**

Literature regarding homicidal cases is scarce. Pesticide-related fatalities are mostly due to suicidal or accidental poisoning with a minority being due to homicidal poisoning, although during the middle 20<sup>th</sup> century more such cases were apparent (De Letter *et al.*, 2002). A case report by De Letter *et al.* (2002), discusses a case of homicide and an attempted homicide. The suspect repeatedly administered poison to his wife. An organophosphate insecticide (unspecified) was added to cold drink and the deceased died a few days after becoming ill. The suspect also attempted to poison a friend by adding poison to his coffee (De Letter *et al.*, 2002). Fortunately the friend received immediate treatment and was diagnosed with mild parathion intoxication (De Letter *et al.*, 2002).

Two homicidal cases discussed by Tennakoon *et al.* (2013) involved the poisoning of children aged 3 and a half years and 10 years old respectively. Carbofuran was added to their soft drinks and given to the children by relatives, and was ingested by the children (Tennakoon *et al.*, 2013). Carbofuran has a distinct colour and has a bitter taste, it is possibly due to this that in both cases discussed above, the poison was mixed in soft drinks to camouflage the appearance and colour (Tennakoon *et al.*, 2013).

Determining the cause and manner of death in pesticide-related poisonings can prove challenging as the clinical manifestations of pesticide poisonings may closely resemble that of other illnesses. However, should pesticide poisoning be suspected adequate analytical assays are available to confirm such diagnosis.

#### **5. Analytical assays**

An array of methods is available for the identification and quantitation of pesticides in various biological matrices, of which a few are discussed here. Analysis of these compounds extends from the use of Thin Layer Chromatography (TLC) (e.g. Carbofuran identification in biological

specimens (Ferslew *et al.*, 1992) to mass spectrometric techniques (Tarbah *et al.*, (2001). Tarbah *et al.*, (2001), analysed a variety of 23 different Organophosphates in both biological samples as well as food samples. Samples included blood, plasma, urine, gastric fluid, food products and pesticide products. Analysis was performed using Gas chromatography mass spectrophotometry (GCMS). The stability of Organophosphates in aqueous solutions and blood are weak, leading to possible degradation when stored (Tarbah *et al.*, 2001). In addition, esterase enzymes cause rapid degradation in comparison to other chemical mechanisms (Tarbah *et al.*, 2001). Organophosphates on the other hand, are hydrolysed chemically in aqueous solutions, but are stable in biological samples. Sodium fluoride that is present in test tubes used for blood collection is suggested to degrade OP's leading to negative result when samples are analysed (Moriya *et al.*, 1999). Sodium fluoride, formaldehyde and storage temperature contributes to the preservation and degradation of organophosphates (Wei *et al.*, 2016). Sodium fluoride and ammonium chloride and Ethane diamine tetraacetic acid (EDTA) was used for stability testing. Sodium fluoride and ammonium chloride proved ineffective to preserve samples as samples were totally degraded after 24h after storage at both 4°C and -20°C. EDTA however proved to be effective if immediate extraction was not possible at a storage temperature of -20°C (Tarbah *et al.*, 2001). The one step extraction of an array of samples was proven to be effective in this study, to determine OP concentrations. Simultaneous and rapid analysis of OP's is possible using solid phase extraction and GC/MS analysis (Park *et al.*, 2009). Lacassie *et al.*, (2001) used both GC/MS as well as LC/MS systems for pesticide analysis.

## **6. Medico-legal investigations in South Africa**

In South Africa, autopsies are performed in terms of the Inquests Act (Act no. 58 of 1959) and the National Health Act (Act No. 61 of 2003). All autopsies performed at Salt River mortuary occurs due to an inquest being opened by the South African Police Service, if the deceased died due to unnatural causes. All suspected cases of unnatural death – death due to criminal activity, omission or commission, chemical or physical means, procedure-related or sudden, unexpected and unexplained deaths - have to undergo autopsy (Inquest Act, Act no 58 of 1959). These autopsies can only be performed by an authorised forensic medical practitioner

(Du Toit & Saayman 2012). A medico-legal autopsy usually includes an external and internal examination of the body, as well as collection of specimens, tissues or other items for further ancillary investigations (e.g. toxicology and histology etc.). The pathologist can collect any specimens that will assist in their determination of cause of death (Inquests Act, Act no. 58 of 1959). In South Africa, the manner of death (homicide, suicide, accidental, undetermined) will be determined by the legal courts, when the judges interrogate all investigations associated with a case.

The Forensic Pathology Services of the Western Cape Government, Department of Health provide medico-legal and death investigative services to the Western Cape since 2006 and 17 mortuaries are located in the province to fulfil this purpose. Tygerberg and Salt River state mortuaries are two academic medico-legal facilities serving the Metropole of Cape Town (containing a population of approximately 3.74 million individuals). Salt River mortuary is one of the busiest mortuaries in the province and all cases of suspected unnatural death from the West-Metropole of Cape Town (including both formal and informal areas of various socio-economic statuses) are admitted to this academic mortuary. Here pathologists conduct on average 3700 or more autopsies per year.

While cases of pesticide-fatalities should be documented and notified to public health authorities, this is not always performed, particularly in cases in which ancillary investigations (e.g. toxicology) were requested and the case is still under investigation as results were not yet completed. This poses challenges to public health initiatives and also limits the understanding of these cases and the burden they place on the public health and criminal justice systems and the community of the Western Cape.

### **Conclusion:**

Pesticide toxicity is a major cause of morbidity and mortality worldwide. Despite the obvious crisis of the occurrence of pesticide-related poisonings, the issue is not sternly addressed by governments to prevent such poisonings by adequate regulations, and campaigns to combat the problem. The adequate training of health care professionals to consider pesticide-related poisoning when diagnosing patients to ensure prompt treatment is of paramount importance and will positively contribute to decrease pesticide fatality rates. There is limited data available on fatalities, particularly in South Africa. Currently in Cape Town, we are unfamiliar



with the prevalence of pesticide fatalities and our understanding of the characteristics, presentation and findings in these cases post-mortem are limited, particularly as they relate to specific types of pesticides. This study aimed to bridge that gap and provide a stepping-stone for further research and investigation into pesticide-related fatalities in Western Cape, South Africa.

## **Chapter 2 - Manuscript**

## Chapter 2: Retrospective Analysis of Suspected Pesticide-Related Fatalities Admitted to Salt River Mortuary in the West Metropole of Cape Town, South Africa.

### Abstract

### Introduction

Acute pesticide-related toxicity has been reported to contribute to morbidity and mortality rates globally. This is especially true in developing countries where the use of pesticides is elevated and often unregulated. While there are beneficial use of pesticides, particularly within agriculture; the accidental and intentional exposure to these chemicals has called for increased regulations and restrictions for their use. Data has illustrated that low socioeconomic areas are adversely affected by pesticide use and exposure, particularly when used for domestic purposes (Peshin et al, 2014). Lack of education, poor parental supervision, small homes and inadequate storage facilities within these areas reportedly contribute to the occurrence of pesticide-related poisonings (Balme et al, 2012).

In South Africa, agricultural grade pesticides are sold informally within lower socioeconomic areas and are commonly used to combat domestic pest invasions. These have been referred to as *street pesticides*: agricultural pesticides that are decanted and sold as concentrated or diluted liquids or granules in unlabelled bottles or packages for unregistered use (Rother, 2010). While these pesticide formulations are often cheaper and readily available in poor informal settlement areas, they are highly toxic and often illegal. In 2010, Rother reported the selling of analytically confirmed toxic carbamate (aldicarb), organophosphate (methamidophos and chlorpyrifos) and pyrethroid (e.g. cypermethrin) pesticides in the urban periphery of Cape Town for the use of domestic pest control (Rother, 2010).

These *street pesticides* pose increased exposure risks to both vendors and users due to their highly toxic, unregulated and mixed formulations, which contribute to the difficulty in diagnosing specific pesticide poisonings in health care facilities (Balme 2010). In South Africa, data relevant to hospitalisation due to pesticide-related poisonings are lacking due to inadequate reporting and documenting or non- or mis-diagnosing within health care facilities.

A lack of information currently exists concerning the prevalence and characterization of acute pesticide fatalities in South Africa. This has resulted in health professionals having

limited insight into the contribution of pesticides, and *street pesticides* in particular, to the overall health burden and mortality rates in the country. This retrospective study intends to broaden the spectrum of knowledge concerning pesticide-related deaths within the West Metropole of Cape Town by investigating suspected pesticide fatalities in cases admitted to Salt River Mortuary for medico-legal post-mortem investigations. Diagnostic identification of these cases, together with identification of the pesticide agents responsible for fatalities is of importance, as this will aid in improving surveillance, reporting of related medico-legal cases, as well as to identify required intervention strategies, particularly in policy surrounding the use of toxic unregulated street pesticides.

## **Methods**

### ***Data Sampling***

Preliminary cases of suspected pesticide toxicity deaths from January 1<sup>st</sup>, 2011 to December 31<sup>st</sup>, 2015 were identified using the electronic Office Autopsy Database (HREC ethics: R036/2014), at the Division of Forensic Medicine and Toxicology, University of Cape Town. Cases were screened according to their captured manner and method of death. Any cases indicating suspected pesticide toxicity at the death scene, at hospital, at autopsy or following toxicological screening were isolated as suspected pesticide-related fatalities.

Cases were then screened for further review using keywords such as: “Pesti”, “Granules”, “Pepper”, “Ogano”, “Carba”, and “Rodent”. Any positive results for these searches were then cross referenced to the isolated list of cases to ensure that they were included.

All suspected cases following screening were individually investigated by reviewing the forensic pathologists’ post-mortem report with available scene and ancillary investigation data to confirm whether it was a pesticide-related fatality. All confirmed or suspected acute pesticide fatalities (e.g. if undetermined, awaiting toxicological testing) were documented and non-pesticide related deaths (e.g. drug overdoses other non-pesticide chemical ingestion) were excluded.

Confirmed cases included those in which the physician in hospital indicated that pesticides were ingested and the clinical symptomology confirmed this; any cases with a clear history of pesticide intake from family or scene evidence (with or without confirmed toxicological

results); cases in which evidence of pesticide intake was observed at autopsy (e.g. black granules in the stomach) and/or if the pathologist determined the death to be caused by acute pesticide toxicity. Scene information together with case history of the deceased was useful in the inclusion of cases especially in instances where toxicological analysis was lacking. Cases of suspected drug toxicity with pending toxicology results were excluded. In addition, only acute toxicity was investigated and no cases of chronic pesticide toxicity were included.

### ***Data collection and analyses***

All the cases identified to be pesticide-related fatalities were comprehensively reviewed and data of interest was extracted from each individual case file and recorded on Excel 2013. Cases were allocated unique study numbers ensuring anonymity of the deceased. Data collected from autopsy reports included the following where information was available: Date and day of death, date of post-mortem, time of death, scene of Injury, hospital admission date and findings (if applicable), type of residence, residence suburb, race, sex, age, chief post-mortem findings, manner of death, and method of death. In addition, information was recorded on post-mortem specimen collection, whether toxicological analyses were requested, and if available, what the toxicological results were. Toxicological analyses were performed by the National Department of Health's Forensic Chemistry Laboratory based in Woodstock, Cape Town (one of only four national government laboratories currently performing post-mortem toxicology in the country). Basic descriptive statistics was performed on collated data. This included measures of central tendency, such as mean values.

### ***Ethics***

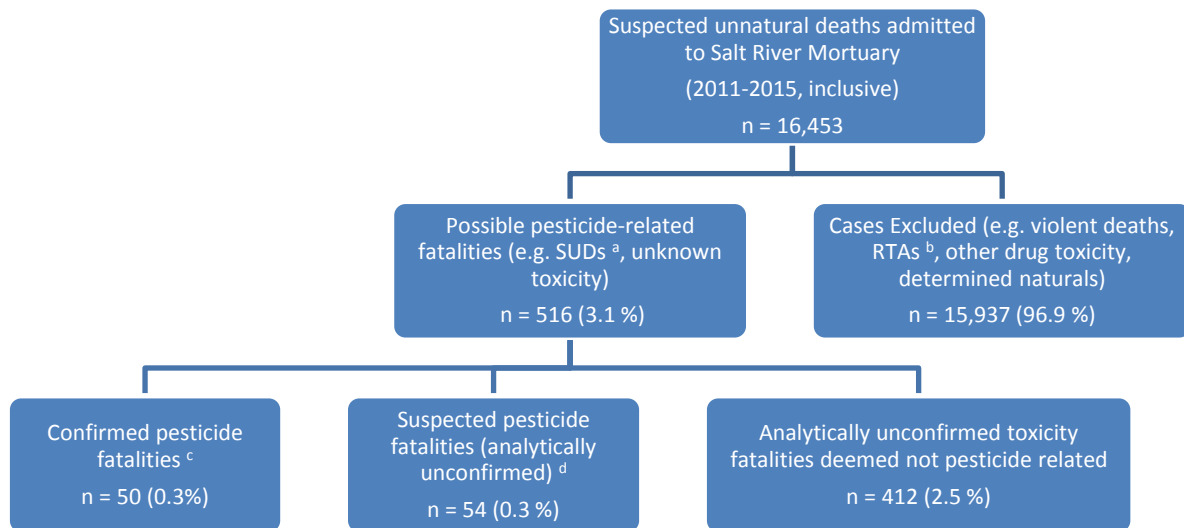
This study received ethics approval from the Health Research Ethics Committee (HREC) of the Faculty of Health Sciences at University of Cape Town (UCT) (HREC REF: 220/2016).

## **Results**

### ***Included Case Data***

A total of 16,453 suspected unnatural death cases were admitted to Salt River Mortuary between 01 January, 2011 to 31 December, 2015 (inclusive). After data screening was completed, 516 cases were identified and isolated to be possible toxicity deaths where

pesticides may have been involved. Following review of pathology, scene and ancillary investigations, 104 pesticide-related fatalities were identified (Figure 1). These include pesticide fatalities in both adults ( $n=81$ ; age  $\geq 18$ ) and children ( $n=23$ ; age  $\leq 17$ ).



<sup>a</sup> SUDs : Sudden, unexpected and unexplained deaths at autopsy (no medical history), where the cause of death may/may not be determined at autopsy alone. Following further ancillary investigation results (e.g. toxicology and histology a cause of death will be determined or the will remain undetermined.

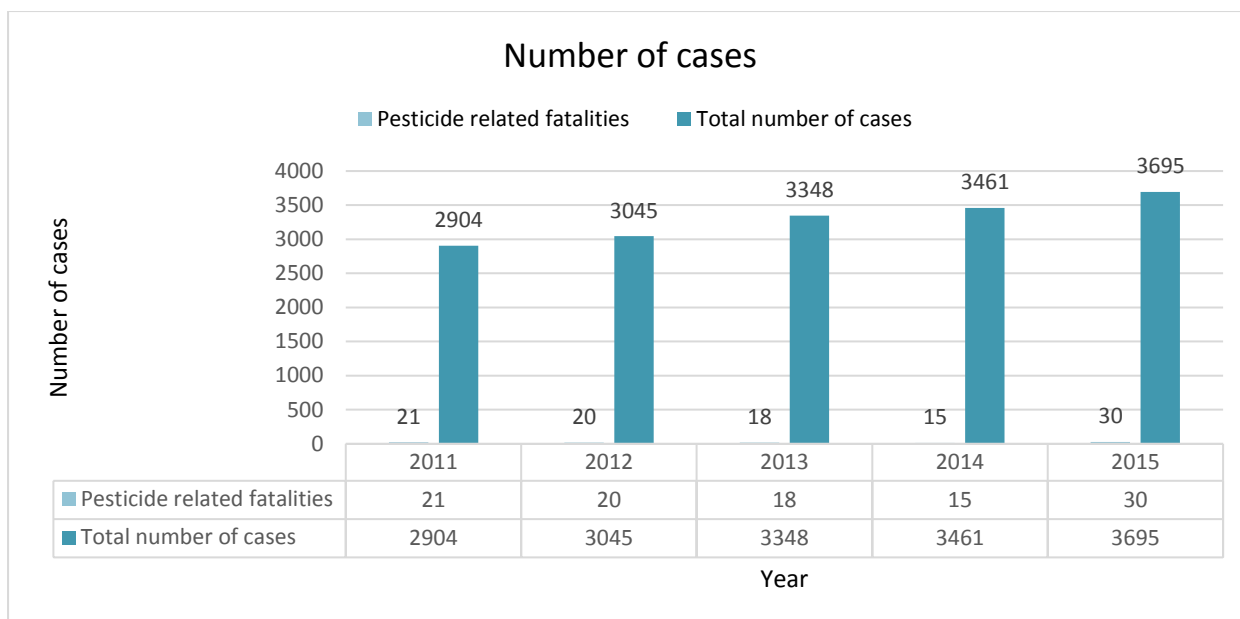
<sup>b</sup> RTAs = Road traffic accidents

<sup>c</sup> Confirmed cases were analytically confirmed to be pesticide related due to the detection of pesticides in biological samples.

<sup>d</sup> Suspected pesticide fatalities were not yet analytically confirmed by FCL but ancillary information (pathologist's and/or hospital findings, scene information or history) provided enough reason for these cases to be included in the study.

**Figure 1:** Flowchart illustrating the total number of cases reviewed and the identified pesticide-related cases for the five year study period.

Out of the 104 cases investigated, most occurred within 2015 (Figure 2). The ratio of pesticide cases to overall admissions for 2011 was 0.72%, 2012 was 0.66%, 2013 was 0.54%, 2014 was 0.43% and 2015 was 0.81%.

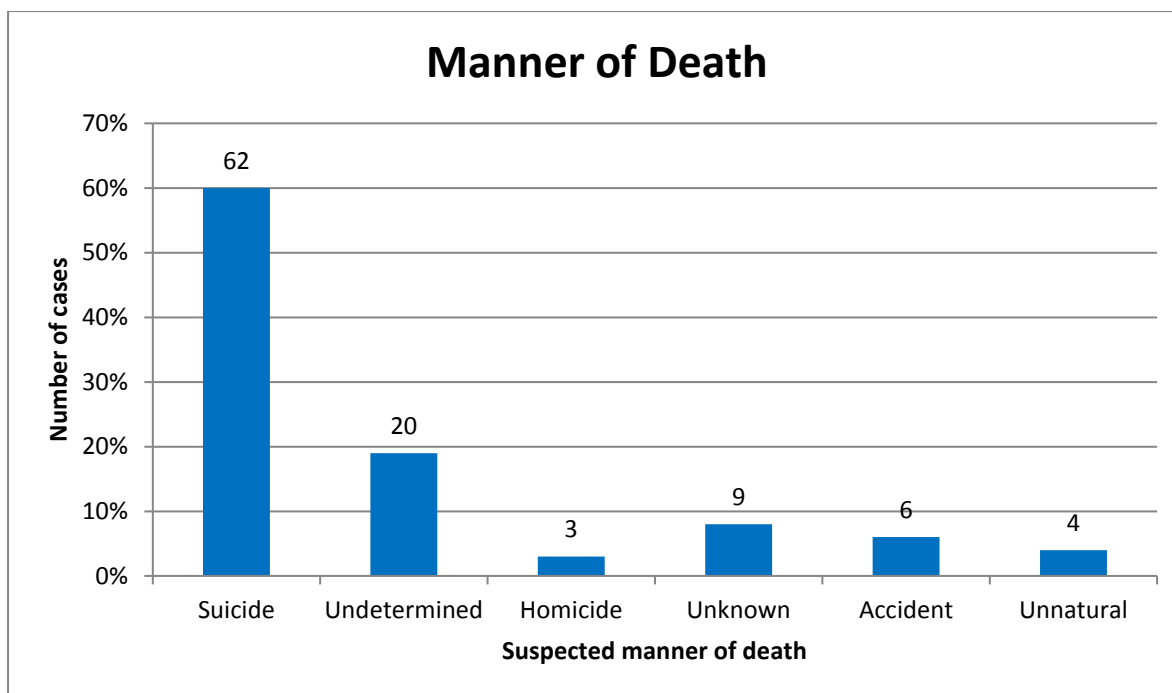


**Figure 2:** The total number of pesticide related fatalities identified per year from 2011 to 2015 (inclusive) compared to the total amount of cases submitted.

### **Suspected Manner of Death**

Mortuary admission circumstances and suspected manner of death of the 104 included cases reported by the pathologists and forensic officers largely consisted of suspected suicide ( $n=62$ , 60%). Three cases of suspected homicides of children aged approximately one day old to 9 months old were reported. Six cases were classified as suspected accidental poisoning, 3 of which included children aged 12 to 18 months old, two adult males aged 26 and 30 years respectively as well as a 94-year-old female.

The remaining cases were initially classified by the pathologist's as undetermined in 19% ( $n=20$ ), unknown 9% ( $n=9$ ) and unnatural 4% ( $n=4$ ) and all being pesticide-related deaths identified on the merits of toxicological, death scene or case history (Figure 3). It must be noted that this is not the final determined manner of death, only that purported by the forensic pathologist. The final determination will be made by the inquest magistrate following a full court inquest into death.

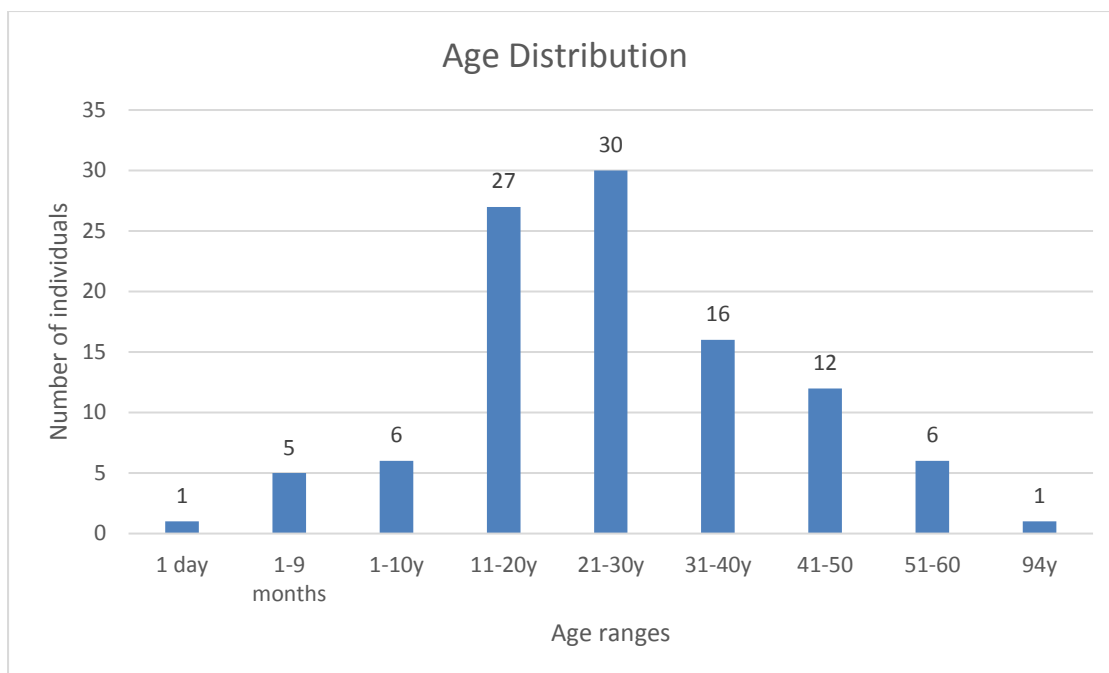


**Figure 3:** Suspected manner of death determined by the forensic pathologists following autopsy and possible completed ancillary investigations.

### Demographic data

An equal number of males (n=52; 50%) and females (n=52; 50%) decedents were identified. The mean (median) age of the sample cohort was 26 (23) years. The 25<sup>th</sup> percentile age was 18 years (Q1) and the 75<sup>th</sup> percentile age was 35 years (Q3). Age range 20-30 years (n=30, 28%) were most represented followed by the age range 11-20 years (n=27, 26%) (Figure 4). The youngest death was that of an abandoned new born baby reportedly one day old. Black pungent pepper-like granules (indicative of a pesticide) were present in his stomach content. The eldest victim was a 94-year-old female who was reported to accidentally have ingested an organophosphate. Clinical symptoms of hyper-salivation, copious secretions and pinpoint pupils were reported and consistent with the pesticide ingestion observation.





**Figure 4:** Age distribution of cases identified as acute pesticide-related deaths.

Racial distribution within this cohort indicated that most pesticide-related victims were of Black African descent accounting for 84% (n=87) of cohort cases. The Coloured and White samples were represented in the minority with 9% (n=9) and 8% (n=8) of cases respectively.

#### **Day of death**

The actual day of the week that death was declared was recorded and analysed, to establish if any patterns exist. The day of death declaration was nearly equally distributed. The same was done for the factor of season per year (Table 1).

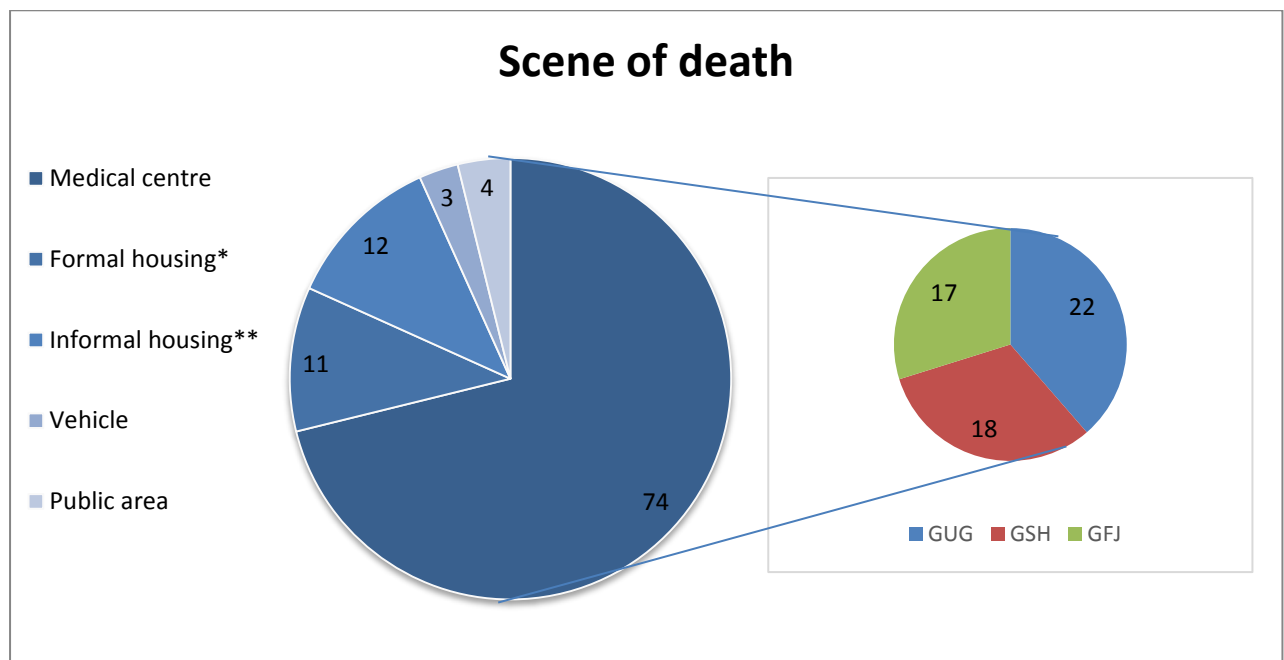
**Table 2:** The number of pesticide related toxicity cases per season (and displayed per year).

Season	2011	2012	2013	2014	2015	Total number of cases per season (per year)
<b>Summer</b> (December - February)	5	5	4	3	9	26
<b>Autumn</b> (March - May)	7	7	7	2	9	32
<b>Winter</b> (June - August)	7	5	4	5	5	26
<b>Spring</b> (September - November)	2	3	3	5	7	20
<b>Total number of cases per year</b>	21	20	18	15	30	-

Autumn displayed the most occurrences followed by summer and winter with an equal amount of occurrences. The least amount of pesticide related toxicity cases occurred during spring.

**Death scene and findings**

The majority of fatalities ( $n=74$ ; 71%) occurred at medical centres following acute exposure, attempted treatment, and subsequent death (Figure 5). For 12 cases the scene of death was in a formal house and 11 death scenes were reported as informal housing. In 3 cases the death scene was reported as being in a vehicle and for 4 cases the scene of death was in a public area, such as a bench on a sidewalk and an open field for example.



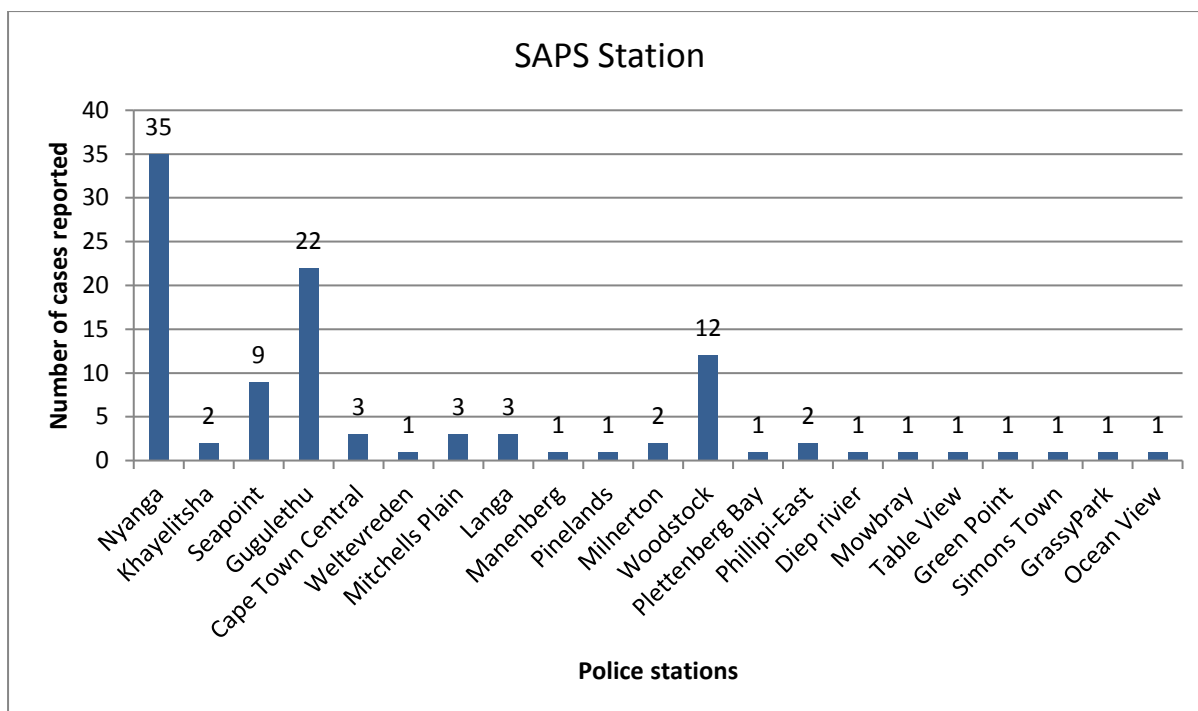
\*A formal urban settlement is structured and organised. Services such as water, electricity and refuse removal are provided, roads are formally planned and maintained by the council.

\*\*Informal housing refers to an informal dwelling (shack) settled in an unplanned settlement on land which has not been surveyed or proclaimed as residential.

GUG- Gugulethu Hospital ; GSH – Groote Schuur Hospital ; GFJ – GF Jooste Hospital.

Other hospitals included: Mitchells Plain 9 (Day and Medi-clinic), Somerset Hospital 8, Blaauberg hospital 1, Hanover Park Hospital 1, Red Cross Children’s Hospital 1.

**Figure 5:** Scene of death for 104 included cases, with additional information on hospital admissions.



**Figure 6:** SAPS police stations where cases were opened.

When looking at the two above figures (Figure 5 and Figure 6) it becomes difficult to determine why the entries of cases reported to Police stations may not correspond to the number of incidents at a particular hospital in the same area. Possible explanations may be that cases are opened at a specific station and thereafter transferred to another Police station and similarly cases submitted to one hospital may later be transferred to a different hospital. However, not all cases reported to SAPS stations are hospital cases.

Observations documented by forensic officers on non-medical centre death scenes ( $n=30$ ), included foaming at the mouth ( $n=8$ ), vomiting ( $n=5$ ), and secretions from mouth and nose ( $n=4$ ) (Table 2). Witnesses describe the victims complaining of diarrhoea ( $n=3$ ), stomach pain ( $n=2$ ), and shortness of breath ( $n=1$ ), or having seizures ( $n=3$ ) prior to death. A suicide note was present in only one case. In only 5 cases the poisonous agent was still present on the scene.

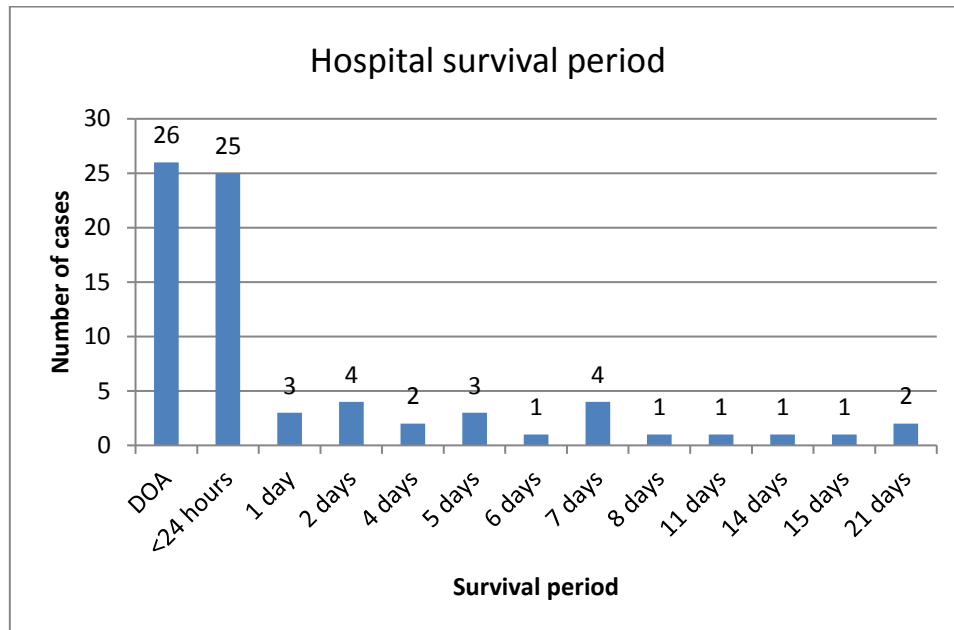
**Table 3:** Observations and ancillary information pertaining to occurrences in the deceased noted on the scene of death in non-hospital and hospital deaths.

Scene observation	Number of observations	Hospital observations	Number of observations
Foaming at mouth	8	Foaming at mouth	2
Poison present on scene	5	Unresponsiveness	9
Vomiting	5	Vomiting	5
Increased secretions	4	Increased secretions	14
Diarrhoea	3	Diarrhoea	1
Seizures	3	Seizures	6
Stomach pain	2	Stomach pain	1
Shortness of breath	1	Atropine treatment	13
Suicide note	1	< Pseudocholinesterase level	16
History of ingestion / reported poison	57	History of ingestion / reported poison	16
Previous suicidal ideations	5	Organophosphate suspected	28
Arguments prior to event	4	Resuscitation attempted	15
Depression	3	Pin-point pupils	24

The information in Table 2 is solely dependent on the information recorded within each case file with reference to the scene of death and that recorded in hospital notes. The inclusion of the history of cases provides further insight into the circumstances surrounding the death. In a large amount of cases (n=57), it was reported by the witnesses or investigating officers that a poison was ingested. In four cases the recent use of traditional medicine was reported. Traditional medicine is popular amongst the Black population of South Africa and in all 4 cases Black Africans were involved, two of which was babies and the traditional medicine was added to their feeding bottles. The ingredients of such traditional medicine are unknown and this causes concern.

Hospital admissions were documented at 10 different hospitals and patients varied in survival times. In many cases death occurred prior to hospital arrival (DOA) or on admission and within 24 hours after hospital admission. Hospital notes reported on symptomology and procedures on arrival at hospital. Pin-point pupils, diarrhoea, secretions and lowered pseudocholinesterase levels were tell-tale signs of pesticide (particularly OP poisoning). Resuscitation was attempted in a number of cases and atropine treatment was undertaken in many cases.

Most cases were admitted to the larger 3 hospitals of Cape Town Gugulethu ( $n=20$ ), (Groote Schuur ( $n=11$ ), and GF Jooste ( $n=17$ )), and most cases were reported in areas with large informal settlements (Nyanga and Gugulethu) with larger Black African populations (Figure 6).



DOA: Dead on arrival

**Figure 7:** Hospital admissions and survival periods of all cases (children and adults).

### Autopsy Findings

The post mortem (PM) interval hereby pertains to the date at which death was declared and the date when the autopsy was performed. The mean post mortem interval was 3 days with a SD of 1.6 across all five years. The minimum PM interval was 1 day with the maximum PM interval being 12 days. (25<sup>th</sup> percentile=2, 75<sup>th</sup> percentile=4).

**Table 4:** Chief post mortem findings.

Autopsy findings	No. of occurrences	% of the total
Granules in stomach.	49	47%
Congested organs	24	23%
Dark fluid (stomach)	20	19%
Pulmonary oedema	12	12%
Chewing gum pellets	1	1%
Signs of aspiration	1	1%

<b>Tracheal necrosis</b>	1	1%
<b>Secretions (mouth/nose)</b>	4	4%

The stomach content of 47% (n=49) of the cases was described by the pathologist as containing black, grey or blue granules respectively and further more dark pungent fluid was observed in 19% (n=20) of cases. The specific pesticide involved could not be identified without formal toxicological analyses. Congested organs were reported in 23% (n=24) of cases and together these three variables was predominantly present, followed by pulmonary oedema that was observed in 12% (n=12) cases. Secretions from the mouth and nose were reported in 4 cases. Referring to the presence of granules in the stomach content (n=49), the presence thereof was noted in 17 (35%) cases in which the individual was declared dead on arrival at hospital. In 16 (33%) cases that survived for less than 24 hours, 4 (8%) cases that survived for more than 24 hours and in 12 (24%) cases where no hospital admission was reported. The PM interval in these cases were 4 days with the shortest period being one day and the longest PM interval being 22 days.

### ***Post-mortem Toxicological Analyses***

Specimens collected for post-mortem toxicological analyses over the five years included femoral blood, gastric contents, bile, urine, and vitreous humor. Specimens were collected in a total of 97 cases (93%) and the number of times each specimen was collected is illustrated in Table 4. Blood, bile and stomach contents combinations were most commonly submitted.

**Table 5:** *Specimens collected for pesticide screening and positive results obtained per specimen.*

<b>Specimen collected</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>Total number of specimen collected</b>	<b>Number of positive results</b>
<b>Stomach content</b>	17	10	14	12	22	75	49
<b>Blood</b>	20	15	16	14	26	91	1
<b>Bile</b>	13	12	10	6	14	55	4
<b>Urine</b>	12	9	9	3	12	45	0
<b>Vitreous humor</b>	0	0	4	2	9	15	1

Pesticides were detected in 53 cases (50%) overall, and were largely identified from the stomach contents (n=49). Few other specimens were positive for pesticides including bile

( $n=4$ ), blood ( $n=1$ ), and vitreous humor ( $n=1$ ). Pesticides were not detected in 18 cases, 11 of which were hospitalised and 4 were declared dead on arrival. A combination of the above mentioned specimens were collected in these 18 cases where no pesticides were detected. Results for 22 cases were not yet available from the laboratory at the time of this study conclusion.

**Table 6:** Toxicological findings of the various pesticides detected in toxicological analysis.

Pesticide	2011	2012	2013	2014	2015	Pesticide classification
<b>Terbufos</b>	9	7	9	5	12	Organophosphate
<b>Methamidophos</b>	1	0	1	0	1	Organophosphate
<b>Chlorpyrifos</b>	0	0	1	0	0	Organophosphate
<b>Diazinon</b>	0	0	1	0	0	Organophosphate
<b>Malathion</b>	0	0	1	1	0	Organophosphate
<b>Cypermethrin</b>	0	0	0	1	0	Insecticide
<b>Sulfotep</b>	0	0	0	0	2	Organophosphate
<b>Diphacinone</b>	0	0	0	0	1	Rodenticide
<b>None requested</b>	3	5	2	5	2	-
<b>Outstanding</b>	5	4	1	4	8	-
<b>None detected</b>	3	4	2	3	6	-

Terbufos was detected in the majority of cases 42% ( $n=40$ ) followed by methamidophos (3%), malathion and sulfotep (2% each) respectively. Chlorpyrifos, Diazinon, Cypermethrin and Diphacinone were each detected in 1 case respectively. Multiple pesticides were detected in 2 cases and the pesticides involved were terbufos and sulfotep.

### Children

8 cases in the population of children was dead on arrival at hospital. Methamidophos and diazinon presented in the results of two children aged 16 years and 18 months respectively. 5 specimens tested positive for terbufos (age ranged from 8 months to 17 years) and in 1 case no pesticides were detected (1 year old).

11 children were submitted to hospital of which only one African female, aged 16 years survived in hospital for more than one day. Terbufos was detected in her stomach content. Of the remaining 10 children (age ranged from 3 weeks to 15 years) that survived in hospital for less than a day, terbufos was detected in 6 of the results tested. No analysis was requested

in 1 case, for 2 cases the results were outstanding and in 1 case no pesticides were detected. Four children were not admitted to hospital and the toxicology results of these cases are outstanding. Data demonstrates the vulnerability of children to the toxic effects of pesticides as all but one child survived for less than a day.

### **Adults**

Of the adult population, 35 cases were admitted to hospital and toxicology results for these included the detection of terbufos in 9 cases with one case including sulfotep. Malathion, cypermethrine and chlorpyrifos was detected in 1 case each. In 10 cases no toxicological analysis was requested, 6 toxicology results were outstanding and in 6 cases no pesticides were detected. Nineteen cases were reported to be dead on arrival at hospital.

In 27 cases no hospital admission was reported and the results for these cases included 12 positive detections of terbufos (age range (19-46years), 1 case of sulfotep detection in conjunction with terbufos (19 year old). In 1 case positive detection of diphacinone (41 year old), and 1 positive detection of malathion (43 year old). In 4 cases no pesticides were detected, in 3 cases no pesticide analysis was requested and for 5 cases the results were outstanding.

No pattern in the hospital survival period was apparent in the adult population, as some cases with positive results were dead on arrival while others survived for a few hours to a few days.

### **Discussion**

A history of ingestion, clinical symptomology at hospital, autopsy findings and toxicological results (when available) assisted in identification of the pesticide fatalities, which largely presented in lower socio-economic communities. The highest number of pesticide-related deaths were identified in 2015, which correlated with a general increase in case load at Salt River Mortuary.

The Black African population was involved in the majority of pesticide related deaths for the time period studied, which may largely be due to the drainage area of the mortuary. Cases were largely from lower-socio economic areas (e.g. Guglethu and Nyanga), where



pesticides are used in domestic environments. The distribution of gender was equal, and this may not necessarily be a true reflection of reality in terms of risk factors. This can be attributed to the small sample size of fatalities identified in this retrospective review. The age range for the majority of cases occurred in the range of 20 to 30 years, most of which were suspected suicide cases. This does suggest that in the context of the broader toxicological paradigm, the ubiquitous nature of these pesticides, particularly in poor informal areas, makes them easy substances to obtain to commit suicide.

Three infants were suspected to have been murdered using pesticides, while three children consumed pesticides accidentally. This indicated the inconspicuous nature of pesticide toxicity to cause death, particularly in the vulnerable child population. The remainder of the study population are suspected to have used pesticides as a means to commit suicide, and included 7 children less than 17 years of age (the youngest being 15 years old), and 55 adults greater than 18 years old, amongst whom females were in the majority. This is extremely worrying, emphasising that these agents are easily accessible and highly toxic compounds being used to commit suicide. The potency of pesticides is reflected in the short survival interval between ingestion and death for the majority of cases, especially in children. It is important to note that the above refers to the suspected manner of death and that the final determination regarding the manner of death will be made by the inquest magistrate.

Some of the key factors observed in hospital or at the death scene were secretions, pin-point pupils, low pseudocholinesterase levels (if applicable) and a history of ingestion. Post-mortem findings were particularly helpful when granules or odours were identified in gastric contents. These identifications were assisting both when toxicology was available (which assisted in identifying the particular agent involved) or if toxicology was not yet available, and was often distinguished by the pathologist as being pesticide related (without identification of the active agent). The collection of specimens for toxicological testing is of paramount importance to ensure conclusive classification of the cause of death. From the available results it is clear that the collection and analysis of stomach content yielded the most satisfactory results, as the specimens of which the results were currently available, reported positive toxicology results for pesticide analysis. Blood was not a suitable specimen, which could be attributed to storage of the sample in sodium fluoride (which has been shown

to cause OP degradation, rapid metabolism or elimination of the parent pesticide, as well as analytical capacity. Terbufos was the pesticide that was predominantly reported in the toxicological analysis. This corresponds directly to the autopsy findings of black granules in the stomach content in the majority of cases. Terbufos is currently not regulated with the urgency that is necessary to prevent the availability for intentional ingestion. Alteration of public policy to better regulate the availability of terbufos is vital in reducing its associated mortality rates.

One of the major challenges with this study was the inability to distinguish mortality associated with chronic pesticide exposure based on available data. This may be identified in future studies by including a more comprehensive follow up on case history such as the occupation of the decedents, where applicable. In addition, identifying whether these cases are related to *street pesticides*, which while likely, would have been easier if scene and history investigations included the photographic documentation and collection of the samples for further analytical confirmation.

In the cases where traditional medicine was used prior to death, no mention of the testing of these traditional medicines in cases of poisoning were reported. A study conducted by Steward et al, (1999), revealed that traditional medicines tested contained chlorpyrifos, aldicarb, carbofuran, melathion and diazinon amongst others. It is therefore important for future studies to include more information regarding traditional medicines used and the testing thereof for pesticides and other poisons.

The outstanding toxicology results limited the accurate reporting of all the pesticides that may be involved and reported on in this review. It is also of paramount importance that the appropriate specimens, particularly stomach content, are collected for toxicological analysis, as the collection of specimens lacked in certain cases. For example, in some cases the history of ingestion is clear, yet only post-mortem blood was collected, which produced negative results. Inclusion of all toxicology results in future studies will be favourable to ensure that results pertaining to the pesticides involved are all inclusive. The results of this project were used to provide the government laboratory with a list of outstanding toxicology cases, which were suspected to be pesticide related. A batch analysis – particularly of stomach contents – was recommended in an attempt to complete these results so undetermined cases

can be determined by the pathologist following returning of the results. At the time of completion of this project, the results had still not been returned, which unfortunately hinder the progress of the justice system and case conclusion in these cases.

In some instances, data descriptions were incomplete and this hindered data collection. An example of this can be referred to the scene of death and the fact that the majority of poisonings was due to Terbufos ingestion. It would be expected that most individuals experience the same “symptoms” of poisoning for example vomiting, secretions from the mouth and nose etc. as these are all typical symptoms associated with the ingestion of Terbufos and onset thereof occurs shortly after ingestion. The absence of these occurrences statistically may merely be that all the information pertaining to each case was not provided or recorded in the respective case files and hence not reported on in this review as the information was lacking. Improving scene investigation and information collection through the use of a pesticide-related questionnaire and scene investigative guideline is recommended for forensic officers conducting these investigations on scene or at hospital.

No information regarding the origin of pesticides used in households of the deceased was collected, making it difficult to determine whether street pesticides were involved in the poisonings. Follow up on this type of information is beyond the scope of this study and provision for such data collection should be included in the planning of future studies and for the scene investigation service itself.

Furthermore only one area was included in this retrospective review and included a 5-year period only, limiting the number of cases for inclusion. An extension of this research to other mortuaries in the Western Cape, and the extension of the time period studied and collaborative work on the availability of *street pesticides* will assist in strategic intervention methods to reduce accidental and suicidal mortality associated with pesticide exposure. This project still provides important insight into the types of unregulated pesticides being used for intentional and accidental ingestion and together with public health groups will provide an evidence-base for policy and practice implications and recommendations.

## **Conclusion:**

Acute and chronic pesticide poisoning has been reported to contribute greatly to global morbidity and mortality, particularly in low income countries. In the Western Cape, pesticide-related deaths are primarily related to acute pesticide exposure, and scene, hospital, autopsy and toxicological investigations all aid in the identification of pesticide-related deaths. Of the 104 cases identified as being pesticide-related over the 5-year study period, only a few accidental poisonings occurred, but these could have been prevented. Pesticides have to be adequately regulated to prevent easy accessibility that can inevitably lead to toxicity, irrespective of the type of poisoning. The availability of *street pesticides*, unregulated and highly toxic pesticides such as aldicarb and terbufos, may contribute to pesticide-related deaths and by eradicating the accessibility of street pesticides many of the pesticide-related poisonings could be reduced (particularly if a less toxic means of pest prevention in domestic environment is recommended).

The increased use of pesticides for means of poisoning can possibly be attributed to the availability thereof within the direct environment of the individuals involved. Further investigation regarding the living conditions, lifestyle and occupation of those affected can positively contribute to the knowledge in this regard. This study shows similarities with the study done by Balme et al, (2012) where low socio-economic environments are predominantly affected by pesticide-related fatalities, where the use of pesticides is expected to be high. It is therefore evident that easy availability of pesticides within these areas is indeed problematic. The availability of pesticides as well as street pesticides, and their high toxicity are suspected to be the leading factor in the number of pesticide-related deaths.

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## **Chapter 3 - Appendices**

1. Ethics Approval Letter
2. Declaration – Manuscript
3. Highlights – Manuscript
4. Funding – Manuscript
5. Turnitin originality report
6. Journal of Forensic Science International, Instructions to authors.

**Declaration:**

I, Meryl J. Patience conducted the research and was responsible for writing the manuscript.

Bronwen Davies provided invaluable guidance and insight into all aspects of the research and the manuscript and.

Together we disclose that we are both satisfied to submit the article for publication.

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**Highlights:**

- Information concerning pesticide-related fatalities in Cape Town is lacking.
- Over a five year period 104 cases were identified from Salt River Mortuary.
- Most cases were positive for terbufos, and young adults from lower-socioeconomic areas were adversely affected, using these agents to commit suicide.
- Children were identified as at risk for accidental ingestion of pesticides.
- The availability and cheap street pesticides together with their toxicity may play a role in these deaths, and policy and regulations of these need to be developed and implemented.
- Bridging the gap in knowledge regarding the lack of information concerning pesticide-related fatalities in Cape Town.
- Continued research in this field is paramount as well as implementation of pesticide surveillance strategies.