Chapter 2
History of the Use and Epidemiology of Organophosphorus Poisoning

Kambiz Soltaninejad and Shahin Shadnia

Abstract Organophosphorus (OP) compounds are organic derivatives of phosphorus that have largely been used as pesticides and nerve agents. Tetraethylpyrophosphate was synthesized in 1854 as the first OP cholinesterase inhibitor. During 1934–1944, Gerhard Schrader, a German chemist at I. G. Farben industries and his coworkers synthesized about 2,000 OP compounds, including parathion as a pesticide and tabun, sarin, and soman as chemical warfare nerve agents. Although the nerve agents had been produced in Germany, they were not applied during World War II (WWII). At the end of WWII, the chemistry of OP compounds developed rapidly. The main use of nerve agents has been reported during the Iran–Iraq war (1980–1988). The Iraqi army used tabun and sarin against the Iranian troops (Majnoon Island) and civilians in Halabjah. In the 1990s, OP nerve agents have gained prominence as weapons of mass destruction and chemical terrorism. The use of sarin in chemical terroristic attacks has been reported during 1994–1995 in Matsumoto and Tokyo subway lines, Japan.

Today, a wide range of OPs with a variety of biological properties are available for agricultural and public health usages including insecticides, nematocides, acaricides, and fungicides. As a result of the widespread use of OPs, OP poisoning is a major cause of morbidity and mortality worldwide, especially in developing countries. OP poisoning shows demographic, seasonal, and regional variations. However, the pattern of OP poisoning is different in developed and developing countries. In this chapter, we reviewed the history of the use and epidemiology of OP poisonings.

Keywords Methyl phosphor chloride · Triethylphosphate (TEP) · Tetraethylpyrophosphate (TEPP) · Parathion · Tabun · Phosphorofluoridates · Diethyl- ·

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M. Balali-Mood, M. Abdollahi (eds.), *Basic and Clinical Toxicology of Organophosphorus Compounds,* DOI 10.1007/978-1-4471-5625-3_2,

Dimethyl- · Sarin · Soman · GA · GB · GD · GF · VX · VR · VE · VG · Di-isopropylfluorophosphate (DFP) · Octamethylpyrophosphortetramide (OMPA) · Paraxon · Malathion · Demeton · Mercaptophos · Dichlorvos · Trichlorfon · Azinphosmethyl · Dieldrin · Heptachlor · DDT · Amiton · Iran–Iraq war · Halabjah · Nerve agents · Majnoon Island · Fao Peninsula · Matsumoto · Aum Shinrikyo Cult · Self-poisoning · Accidental poisoning · Occupational poisoning · Suicidal attempts · World Health Organization (WHO) · Environmental exposure · Integrated Pest Management (IPM) · Organophosphorus compounds · History · Epidemiology · Pesticide · Chemical warfare agents · Poisoning · Exposure · Pattern of poisoning

2.1 Introduction

Organophosphorus (OP) is the general name for organic derivatives of phosphorus. OP compounds are usually esters, amides, or thiol derivatives of phosphoric, phosphonic, phosphinic, or thiophosphoric acids with two organic and additional side chains such as cyanide, thiocyanate, and phenoxy group (Carlton et al. 1998; Balali-Mood and Saber 2012).

OPs are used as insecticides, nematocides, acaricides, fungicides, herbicides, defoliants, fire retardants, solvents, plasticizers, drugs, and chemical warfare nerve agents. They are the most commonly used insecticides in the world (Bey et al. 2001).

Acute poisoning with OPs in humans is frequently observed in many developing countries, and it was estimated that during 2002–2005 around 3,000,000 human beings were poisoned by OP pesticides in the world (Kwong 2002; Eddleston et al. 2005). Severe occupational or unintentional poisoning also happens where such insecticides are used, but deaths are generally uncommon (Carlton et al.1998).

One of the most important aspects of OPs' toxicology is their use as nerve agents in military and terroristic acts as weapons of mass destruction. OP nerve agents have been used as chemical warfare agents (CWA) during the Iran–Iraq war (1980–1988) (Balali-Mood and Balali-Mood 2008). Also, sarin has been used for chemical terroristic attacks during 1994–1995 in Matsumoto area and Tokyo subway system, Japan (Ohbu et al. 1997; Jaga and Dharmani 2003).

In this chapter, we reviewed the history of the use and epidemiology of OP poisoning

2.2 History

2.2.1 History of Synthesis and Development of OP Compounds

In 1837, Von Hofmann synthesized methyl phosphor chloride as an OP compound (Holmsted 1985; Balali-Mood et al. 2012). In 1848, Voegeli produced the first neutral ester of phosphoric acid, the triethylphosphate (TEP) (Petroianu 2010). Numerous

chemists such as Philippe de Clermont (1831–1921), Heinrich Limpricht (1827–1909), Georg Ludwig Carius (1829–1875), Hugo Schiff (1834–1915), based on the work of Williamson, produced TEP in an increasingly higher yield (Petroianu 2010).

Clermont produced tetraethylpyrophosphate (TEPP) in 1854. Although TEPP was not the first synthesized OP, it was the first OP cholinesterase inhibitor (Petroianu 2010). TEPP was developed as a substitute for the botanical insecticide nicotine. Although TEPP is an effective insecticide, it is highly toxic and can be inactivated rapidly by hydrolysis (Bey et al. 2001).

In 1932, Lange and Krueger reported the cholinergic nervous system effects, choking sensation, and blurred vision following inhalation of dimethyl and diethyl phosphorofluoridates (Popov and Popov 2009).

In 1934, Dr. Gerhard Schrader, a German chemist at I. G. Farbenindustrie (I. G. Farben), was given the task to develop a pesticide. During this project, Schrader's group synthesized hundreds of OPs including parathion as a pesticide and tabun (dimethyl phosphoroamidocyanidate), sarin (isopropyl methylphosphonofluoridate), and soman (O-Pinacolyl methylphosphonofluoridate) as CWA. They synthesized tabun in 1938, and then sarin. In 1944, Germans developed soman (Balali-Mood and Balali- Mood 2008). These compounds were named after him and his two coworkers. These three nerve agents are known as G agents : GA (tabun), GB (sarin), and GD (soman). The letter G in G agents means "German" (Marrs et al. 1996; Moshiri et al. 2012). Tabun and sarin were studied for use as chemical weapons by Wolfgang Wirth (López-Muñoz et al. 2009).

From 1938 to 1944, Schrader synthesized a series of fluorine-containing esters including di-isopropylfluorophosphate (DFP) and sarin, pyrophosphate esters including TEPP and octamethylpyrophosphortetramide (OMPA), and thio- and thionophosphorus esters including parathion and its oxygen analog paraxon (Bey et al. 2001; López-Muñoz et al. 2009; Tvedten 2012).

During Schrader's project, the pharmacological and toxicological studies of these compounds were carried out in a number of industrial and military laboratories, where Schrader became aware about the toxic effects of these compounds. While the potency of some of these chemicals prevented their usage as insecticides, they were considered to be used as CWA. In this regard, production of stocks of tabun and sarin were carried out in a factory outside of Duhernfurt, near Breslau. During the years 1942–1945, a total of 12,000 t of tabun was produced. Soman was developed for the first time in 1944 at this factory. At the end of the war, the Allies seized large quantities of this nerve agent. Since that time, it is estimated that more than 50,000 organic phosphorus compounds have been developed. Till the end of the war, Schrader and his coworkers developed about 2,000 OP compounds (Tvedten 2012).

British scientists had taken note of the comments of Lange and Krueger concerning the toxicity of acylphosphorofluoridates, and during World War II (WWII) they were paying particular attention to fluorine-containing compounds. A similar line of investigation was being followed about DFP at Edgewood Arsenal in the USA. American and British scientists were well aware about the irreversible anticholinesterase effects of these compounds. When the structures and properties of the tabun and

sarin became known, it was realized that they were two-fold more potent than DFP (Tvedten 2012).

Soon after WWII, researches were mainly concentrated on the mechanisms of the nerve agents with regard to develop more effective methods for protection against these CWA. The results of these investigations led to better forms of protection and also to develop new CWA. At the end of the war and after the exchange of information in the post-war period, the chemistry of OPs developed rapidly, and the decade from 1950 to 1960 can well be named the era of the OP poisons (Tvedten 2012).

By mid-1950, a group of more stable nerve agents had been synthesized, known as the V agents in the American nomenclature. The letter "V" in V agents means "victory." The V agents are sulfur-containing OP compounds (Balali-Mood and Balali-Mood 2008).

VX (S-2 diisopropylamino O-ethylmethylphosphonothioate) is one of the V agents that was produced by the British scientists in the United Kingdom in 1952, almost 20 years after the Germans had produced the G series (Jaga and Dharmani 2003; Moshiri et al. 2012). These compounds are approximately ten-fold more toxic than sarin. The Russians developed a similar nerve agent, variably referred to as VR or "Russian VX" (N, N-diethy-2-methyl-2-methylpropoxy phosphorylsulfanylethanamine) (Popov and Popov 2009; Mikler et al. 2011).

Other members of CWA V-agents series include VE (S-2-diethylaminoethyl O-ethylethylphophonothioate), VM (2-ethoxy-methylphosphoryl sulfanyl-N, N-diethylethanamine), and VG (2-diethoxyphosphorylsulfanyl-N, N-diethylethanamine) (Moshiri et al. 2012).

After the WWII, American companies gained access to some information from Schrader's laboratory, and began to develop OP pesticides in large quantities. Malathion [diethyl (dimethoxyphosphinothioyl) thiobutanedioate] was produced by the American Cyanamid Company in 1950. In 1951, Schrader continued developing new insecticides including Systox® (demeton or mercaptophos, a mixture of the thiono- and thioloisomers of O, O-diethyl-2-ethylmercaptoethyl phosphorothioate), thereby introducing a new class of insecticides having a thioether group. In 1952, the Perkow reaction was first described, in which alpha-halogen carbonyl compounds were reacted with triethyl phosphite resulting in the synthesis of a number of new dialkylvinyl phosphate esters such as dichlorvos (2,2-dichlorovinyl dimethyl phosphate) and trichlorfon (O, O-dimethyl [2,2,2-trichloro-1-hydroxyethyl] phosphate). The thio- and thionophosphorus esters arising from parathion and containing substituted aryl and heterocyclic groups have also been synthesized. Today, a wide range of OPs with a variety of biological properties are available that are used as insecticides, nematocides, acaricides, fungicides, and so on. Parathion, malathion, and azinphosmethyl were among the first marketed OPs. The popularity of these insecticides increased after the ban of many of the organochlorine insecticides like DDT, dieldrin, and heptachlor in the 1970s (Tvedten 2012).

R. Ghosh and J. F. Newman described one of the OPs, known as Amiton, as being particularly effective against mites in 1955. At this time, intensive investigations were developed in Europe and in the USA on the OP insecticides. In 1958, VX has

been known as a CWA in the USA. Mass production of VX began in April 1961, but its structure was not published until 1972 (Tvedten 2012; OPCW 2013).

2.2.2 History of the Use of OPs as CWA

2.2.2.1 Use of OPs as Chemical Warfare Nerve Agents in Military Acts

Nerve agents had not ever been used on the battlefield until the Iran–Iraq war (1980–1988) (Balali-Mood and Balali-Mood 2008). In fact, the famous contemporary use of nerve agents occurred in the Iran–Iraq war. In this conflict, the United Nation (UN) confirmed that Iraq used the nerve agents tabun and sarin against Iranian troops and even civilians including Halabjah (a Kurdish town in Iraq) population. This incident is a prime example of how CWA technology was shared during the Cold War. The Soviet Union at this time armed their allies while the USA did the same. Iraq implemented its chemical stockpiles during the war with Iran. Iraqi troops expanded the use of CWA between 1984 and 1986, which contributed to the tactical military success of Iran. During this period, Iraq began to expand its production capabilities of other nerve agents such as sarin and VX. However, there is no evidence for the use of VX by Iraqis' armed forces against Iran (Ali 2001).

During 1983–1988, nerve agents were infamously used by Iraqi military against Iranian troops and even civilians. Among CWA, sulfur mustard and nerve agents (sarin and tabun, specifically) had been mostly used by Iraq in several chemical massacres (Balali-Mood and Balali-Mood 2008). Tabun was the first nerve agent used in the Iran–Iraq war at Majnoon Island in February 1984. Several thousands were poisoned by tabun and more than 300 victims died within 30 min (Balali-Mood and Balali-Mood 2008). Nerve agents' mortality rate was much more in the first few years of the war because of the unavailability of protective equipment and first-aid medications such as atropine and oximes auto-injectors (Balali-Mood and Shariat 1998; Balali-Mood and Saber 2012; Moshiri et al. 2012). Iraq used more CWA, especially tabun, in offensives to recapture the Fao Peninsula in 1984 (Ali 2001; Balali-Mood and Balali-Mood 2008; Popov and Popov 2009).

From 1987 to 1988, Iraq intensified the tempo and scope of its chemical attacks (Ali 2001). It was estimated that over 100,000 individuals were poisoned by chemical attacks during the Iran–Iraq war (Moshiri et al. 2012).

In March 1988, Iraq used CWA against the Kurdish town of Halabjah. At that time, Iraqi forces bombarded the town with various CWA such as tabun and sulfur mustard for 3 days. The reports indicated that 5,000–8,000 people, including Kurdish civilians, died in this attack (Ali 2001; Popov and Popov 2009).

In two conflicts between USA and Iraq during 1991 and 2003, which have been known as the First and Second Persian Gulf War, none of the countries used CWA. Iraq admitted possession of nerve agents to the USA in 1995 as well as other biologic and chemical weapons (Moshiri et al. 2012). However, in the First Persian Gulf War (1991), US military forces were possibly exposed to sarin and cyclosarin (GF;

fluoromethylphophoryloxycyclohexane) as a result of the destruction of Iraqi munitions at Khamisiyah and Muhammadiyat (McCauley et al. 2001; Jaga and Dharmani 2003).

2.2.2.2 Use of OP Nerve Agents as a Tool in Chemical Terrorism

The first and confirmed report on the use of a nerve agent for chemical terrorism was in 1994 in the residential region of Matsumoto, Japan. The Matsumoto incident was an act of domestic terrorism. The Aum Shinrikyo Cult was reported to have used the nerve agent sarin in public places. In 1994, on the evening of June 27 and the morning of June 28, sarin gas was released from several sites in the Kaichi Heights area. About 12 L of sarin were released by terrorists in Matsumoto. This incident occurred about 9 months before the sarin gas attack on the Tokyo subway (Nakajima et al. 1998; Yanagisawa et al. 2006). Eight people were killed and about 600 residents and rescue staff were poisoned (Tokuda et al. 2006; Yanagisawa et al. 2006).

On March 20, 1995, terrorists released sarin in trains on three different Tokyo subway lines. Sarin was concealed in lunch boxes and soft drink containers and placed on subway train floors. It was released as terrorists punctured the containers with umbrellas before leaving the trains. Over 5,500 were intoxicated with 11 mortalities. These incidents raise some alarms about the new roles that nerve agents play as a tool of terrorists (Ohbu et al. 1997; Nagao et al. 1997).

The chronology of development of OP compounds and the history of major uses of OPs as CWA have been summarized in the Tables 2.1 and 2.2, respectively.

2.3 Epidemiology of OP Poisonings

2.3.1 General Status

Acute pesticide poisoning is a significant cause for morbidity and mortality worldwide, especially in developing countries (Kishi and Ladou 2001). Due to several reasons including a lack of standardized case definition, there are no reliable estimates for determining pesticide-related health effects in the world (Thundiyil et al. 2008), although there is a huge body of evidence on the relation between pesticides exposure and elevated rate of chronic diseases (Mostafalou and Abdollahi 2013).

Studies in developed countries have demonstrated the annual incidence rates of acute pesticide poisoning in agricultural workers to be as much as 18.2 per 100,000 full time workers (Calvert et al. 2004). The pattern of acute pesticide poisoning may be affected by various factors in different regions of the world. In developing countries, insufficient regulatory and surveillance systems, less enforcement, lack of training, less public education, less availability of poison information and control centers, poorly maintained or nonexistent personal protective equipment, and larger agricultural-based populations are the most important factors for the higher incidences of acute and chronic pesticide poisonings (Thundiyil et al. 2008). The

Table 2.1 Chronology of the synthesis and development of OP pesticides and chemical warfare nerve agents

Date	Event
1837	Von Hofmann synthesized methyl phosphor chloride as an OP
1848	Synthesis of triethylphosphate (TEP) by Voegeli
1854	Synthesis of tetraethylpyrophosphate (TEPP) as the first OP cholinesterase inhibitor by Clermont
1932	Lange and Krueger reported the cholinergic effects of dimethyl and diethyl phosphorofluoridates
1934–1944	Dr. Gerhard Schrader, a German chemist at I. G. Farbenindustrie (I. G. Farben) synthesized parathion, paraxon, tabun, sarin, and soman as chemical warfare agents (CWA)
1950	Malathion was produced by the American Cyanamid Company
1951	Schrader developed Systox® (demeton) as a new insecticide
1952	Perkow reaction was first described which resulted in the synthesis of dichlorvos and trichlorfon
1952	VX was produced by the British as one the V agents
1958	VX has been known as a CWA in the United States
1961	Mass production of VX was begun
1970s	After the ban of many of the organochlorine insecticides, OP compounds' popularity has increased

Table 2.2 History of major use of OP pesticides and chemical warfare nerve agents

Date	Event
1984	Iraq used tabun in the Fao Peninsula and Majnoon Islands during the Iran–Iraq war
1984–1988	Iraq used tabun and sarin against Iranian troops during the Iran–Iraq war
1988	Iraqi forces used tabun against the Kurdish town of Halabjah
1990–1991	US military forces were possibly exposed to sarin and cyclosarin as a result of the destruction of Iraqi munitions at Khamisiyah and Muhammadiyat during the Persian Gulf war
1994	The first report on the use of sarin for chemical terrorism in Matsumoto, Japan by Aum Shinrikyo Cult
1995	Terrorists released sarin in trains of Tokyo subway lines

use of pesticides banned in industrialized countries, in particular highly toxic pesticides and improper storage techniques, may provide unique risks in these countries (McConnell and Hruska 1993). In some countries, such as China, Pakistan, India, and Sri Lanka self-poisoning with pesticides is a major public health problem (Ather el al. 2008; Zhang et al. 2009; Murali et al. 2009; Senarathna et al. 2012).

Inconsistent recording methodology, underestimation of the true incidence of poisoning, and lack of a standard case definition for an acute pesticide poisoning are other reasons for these variations (Thundiyil et al. 2008). Prevention and control measures of occupational and nonintentional pesticide poisoning are different from those required for suicidal poisonings. Therefore, it is important to accurately determine the importance of the problem through better estimates and identification of cases and fatalities resulting from acute pesticide poisoning. The common challenges that exist in attempting to determine the scope of the problem are misdiagnosis by

health care professionals, exclusion of outpatients, and lack of accessibility to health care in rural areas (Alavanja et al. 2001).

Also, suicidal attempts with pesticides for the most severe poisoning and consequently hospital-based studies may underestimate the overall occupational/nonintentional incidence of acute pesticide poisoning (Litchfield 2005). Additionally, in many developing countries, lack of the necessary toxicovigilance programs and laboratory facilities for confirmation of all suspected acute pesticide poisoning cases may affect the difference between developing and developed countries in this issue (Thundiyil et al. 2008). The severity and likelihood of acute pesticide poisoning can be related to many factors such as chemical class and identity, dose, route of exposure, formulation type, underlying physiological conditions, comorbidities, coingestion, age, occupation, economic and educational status (Tinoco-Ojanguren et al. 1998; Oliveira-Silva et al. 2001; Mancini et al. 2005).

OPs are the most common pesticides used in most countries around the world to protect agricultural crops against pests (Kazemi et al. 2012). OPs have become increasingly popular for both agricultural and home use because their unstable chemical structure leads to rapid hydrolysis and little long-term accumulation in the environment (Kumar et al. 2010). Their widespread use and accessibility have resulted in increased numbers of human poisonings especially in developing countries (Pratim Maiti et al. 2011).

The number of intoxication with OPs is estimated at some 3,000,000 per year, and more than 80 % of them are pesticide-related hospitalizations. The total fatality rate has been estimated at 20 % (Pratim Maiti et al. 2011).

The first global estimates of the extent of pesticide poisoning were published in 1990 by the World Health Organization (WHO). Based on extrapolations from limited data, it was estimated that 3,000,000 cases of pesticide poisonings occurred worldwide annually with 220,000 deaths, the majority intentional (WHO 1990). The easy availability of toxic pesticides such as OPs that are used in agriculture has made pesticides as the agents of choice for self-harm (Kumar et al. 2010).

The extent of acute pesticide poisoning in agricultural workers, particularly in developing countries, has often been estimated on inadequate information. This information has resulted in global estimates and regional, localized, or field assessments. The used methods include descriptive epidemiology, cross-sectional and case studies. Extrapolations and assumptions to estimate global pesticide poisonings have often been based on chemical-related fatalities in a small number of countries. Therefore, such estimates do not provide reliable data. Epidemiological studies that are based mainly on hospital and poison center data have been biased towards the more severe poisonings, whereas field studies indicate that occupational pesticide poisoning is associated with low toxicity and minor casualties. Many reports do not adequately distinguish between intentional, accidental, and occupational pesticide poisoning statistics or are dominated by cases of intentional (suicidal) poisoning which, by their nature, result in severe toxicity with high mortalities. The majority of reports do not adequately describe whether individual cases are mild, moderate, or severe poisoning. Occupational acute pesticide poisonings in developing countries are a small proportion of overall reported poisoning and are associated with the more

minor effects of pesticides exposure. They are a small proportion (< 1–4 %) of the several million cases of occupational disorders in agricultural workers in the world (Litchfield 2005).

2.3.2 Sources and Types of Exposure

A simple classification of exposure to OPs is: (a) occupational exposure and (b) environmental or nonoccupational exposure (Muldoon and Hodgson 1992; Bey et al. 2001; Jaga and Dharmani 2003).

Workers are exposed to pesticides in their workplaces as a result of the presence of the chemical in the work environment, irrespective of whether the job involves pesticide use. Workers who handle OPs are at higher risk of exposure than the workers who do not handle pesticides directly. Inhalation, dermal, and/or ocular exposure are the most common routes of exposure in most occupational settings (Bey et al. 2001).

Workers who apply pesticides on crops, livestock, or elsewhere are called pesticide applicators (Ciesielski et al. 1994; Bey et al. 2001). They are in direct contact with the OPs as a result of mixing, loading, spraying, and/or transporting the chemicals (Bey et al. 2001). Workers who grow and pick fruits, vegetables, or other crops come into contact with pesticide residues. The main route of entry is by dermal exposure. One of the most important measures for reducing the OPs' occupational poisoning is education of workers for preventive counter measures using an approach to Integrated Pest Management (IPM) (Mancini et al. 2009).

Industrial exposure to OPs occurs in chemical facilities that produce OPs (Sanborn et al. 2002). In this setting, while the production workers are directly exposed to the OPs, all other employees in the manufacturing plants can also be exposed.

Exterminators, who apply pesticides in public places and in private residential homes consist a major group of workers with occupational exposure to OPs (Steenland et al. 2000).

Office workers, who work in offices, are occasionally exposed to pesticides applied by exterminators (Burns et al. 1998). Although pesticide application is not a part of the office worker's job and it is an unintentional exposure, it should be considered as work-related exposure, due to the introduction of OPs into a work environment.

Heath care workers are at risk of exposure to OPs due to secondary contamination as a result of close contact with and handling of the patients who have acute OP poisoning (Dharmani and Jaga 2005).

Veterinary employees can be exposed to OPs from the chemicals applied to animals for pest control (Kazemi et al. 2012).

Prosectors are at risk of exposure as a result of autopsy of intoxicated cases with OPs (Nolte et al. 2002).

During the Persian Gulf War (1990–1991), US military forces were possibly exposed to OP nerve agents such as sarin and cyclosarin as a result of the destruction of Iraqi munitions at Khamisiyah and Muhammadiyat (McCauley et al. 2001; Jaga and Dharmani 2003).

Environmental or nonoccupational exposure occurs at any place where the exposure is not a result of the person's job (Muldoon and Hodgson 1992; Bey et al. 2001). The extensive use of OPs in residential areas constitutes a major form of nonoccupational exposure. OPs' residues remain on various objects and items in a house such as floors, carpets, toys, dinnerware, tables, and so increase the risk of exposure (Lemus and Abdelghani 2000; Fenske et al. 2002). Inhalation and/or dermal contact are the main routes of exposure, although consumption of contaminated foods such as fruits, vegetables, and water could also result in oral OP ingestion (Fenske et al. 2002). For example, the outbreak of food poisoning in Singapore with 105 cases reported due to ingestion of an imported green leafy vegetable (*Brossica alboglabra*) contaminated by two OPs (metamidophos and profenfos) (Goh et al. 1990).

Agricultural workers who are exposed to OPs in their work, and who do not change their clothes may intoxicate their family at home when they return home with contaminated clothes and have contact with their children and other family members (Renner 2002). Exposure to OPs in public places such as restrooms, restaurants, hotels, schools, apartment buildings, hospitals, and parks is another form of nonoccupational exposure among the general population (Jaga and Dharmani 2003).

Suicidal OPs poisoning is a major health issue in developing countries (Jaga and Dharmani 2003).

Since some OPs are CWA, the threat of terrorism with these agents is a serious public health concern in many countries (Ohbu et al. 1997; Blazes et al. 2002). A South African religious leader was a victim of chemical terrorism with an OP that had been placed in his suitcase by a member of a South African military unit in 1989 in his trip to the USA (Bjornsdottir and Smith 1999).

Outbreaks of OPs mass poisoning regularly occur in many regions of the world especially in the developing countries, and less commonly in the USA, from contamination of crops or food. For example, in the autumn of 1942, a strange epidemic paralysis started in Saval (Verona, Italy). In this incident, 41 people were exposed who were working as owners or laborers on the same farm. Some of the farm animals also became ill. The outbreak was initially diagnosed as polyneuritis with a probable viral cause. Fifty years later, seven people with sequelae of the disease were examined. The clinical syndrome can now be attributed to tri-ortho-cresyl phosphate-induced delayed polyneuropathy (Tosi et al. 1994).

Another OP pesticide mass poisoning was reported from Sierra Leon, West Africa. In June 1986, an epidemic of poisoning occurred in this place and involved 49 persons with 14 deaths. The toxicant was identified as parathion, a highly toxic OP pesticide. Analysis of various items supported the epidemiologic hypothesis that bread was made from contaminated flour and that the flour had become contaminated with parathion during a truck shipment (Hill et al. 1990).

Dewan et al. (2008) reported a mass ethion poisoning with high mortality from India. In this event, 15 people who consumed a meal during a social ceremony at a remote farm developed symptoms and signs of OP poisoning. Information was gathered from villagers and doctors at the primary health center and district hospital. Serial measurements of plasma and red blood cell cholinesterase activity levels were carried out and ethion was identified in blood samples. Clinical toxicity included

http://www.springer.com/978-1-4471-5624-6

Basic and Clinical Toxicology of Organophosphorus Compounds

Balali-Mood, M.; Abdollahi, M. (Eds.)
2014, XII, 257 p. 31 illus., 6 illus. in color., Hardcover
ISBN: 978-1-4471-5624-6