CHEMICAL RISK IN AGRICULTURE: THE ORGANOPHOSPHORUS PESTICIDES AND EFFECTS ON WORKERS' HEALTH

RISCHIO CHIMICO IN AGRICOLTURA: GLI ORGANOFOSFORICI ED EFFETTI SULLA SALUTE DEL LAVORATORE

Giorgi DA[1], De Sio S[2], Mandolesi D[2], Arcangeli L[1], Simonetti T[1], Rosatelli I[1], Sposato S[3], Morali G[3], Bonifazi M[3], Pasquazi G[3], Bertini R[3], Massoni F[4], Ricci S[4]

[1] ARPALazio – Environment and Health Service – Provincial Section of Rome
[2] Department of Anatomical, Histological, Forensic Medicine and Orthopedic Sciences, Unity of Occupational Medicine, "Sapienza" University of Rome
[3] ARPALazio – Laboratory Service – Provincial Section of Rome
[4] Department of Anatomical, Histological, Forensic Medicine and Orthopedic Sciences,"Sapienza" University of Rome

[1] ARPALazio – Servizio Ambiente e Salute – Sezione provinciale di Roma
[2] Dipartimento di Scienze Anatomiche, Istologiche, Medico Legali e dell'Apparato Locomotore, Unità di Medicina del Lavoro, "Sapienza" Università di Roma
[3] ARPALazio - Servizio Laboratorio –Sezione provinciale di Roma
[4] Dipartimento di Scienze Anatomiche, Istologiche, Medico Legali e dell'Apparato Locomotore, "Sapienza" Università di Roma

Citation: Giorgi DA, De Sio S, Mandolesi D, at al. Chemical risk in agriculture: the organophosphorus pesticides and effects on worker health. Prevent Res 2012; 2 (3): 272-280

Key words: organophosphorus pesticides, chemical risk, agricolture

Parole chiave: fosforganici, rischio chimico, agricoltura

Abstract

Background: The use of pesticides in agriculture is justified by the need to increase crop production and reduce the incidence of diseases sometimes very serious as malaria, yellow fever or bubonic plague. But behind the use of these substances lies the risk of occupational diseases confirmed by studies that focus primarily on specific types of substances.

Objectives: The authors, based on an epidemiological premise of the chemical risk arising from the findings of positive cases in the province of Rome by the Lazio Regional Environmental Protection (ARPALazio), conducted a study of health effects resulting from the workers exposure to organophosphorus insecticides.

Methods: 199 fruit samples were analyzed in 2008 and 203 in 2009 as follows: 12.68% apples, 11.69 % pears, 12.93% peaches, 6.46% grapes, 5.72% strawberries, 22.13 % citrus, 7.96% exotic fruits, etc.

Results: Despite a substantial decrease in the number of fruit samples with no pesticide residue (72.36% in 2008 and 65.51% in 2009), there are reasons of deep concern due to the number of samples with at least one pesticide residue (21.10% in 2008 and 22.6% the following year), but especially those with two or more pesticide residues that in a period of 12 months has more than tripled (3.01% in 2008 and 9.85% in 2009).

Discussion and Conclusions: The epidemiology of the phenomenon of pesticide use in agriculture must be seen not only in terms of consumers, but in view of an occupational hazard among farmers. A type of chemicals most frequently encountered, especially in the cultivation of peaches, citrus, grapes and strawberries are Dimethoate and Chlorpyrifos, insecticides, in the category of organo-phosphate, with a dangerous neurotoxic activity.

Abstract

Introduzione: L'uso di pesticidi in agricoltura è giustificato dalla necessità di aumentare la produzione dei raccolti e ridurre l'incidenza di malattie talvolta anche molto gravi come malaria, febbre gialla o peste bubbonica. Tuttavia dietro l'uso di queste sostanze si cela il rischio di malattie professionali confermato da studi che richiamano l'attenzione soprattutto su specifiche tipologie di sostanze.

Obiettivi: Gli Autori, da una premessa epidemiologica del rischio chimico derivante dai casi di positività agli accertamenti effettuati in provincia di Roma dall'Agenzia Regionale Protezione Ambiente Lazio (ARPALazio), procedono ad un approfondimento degli effetti sulla salute dei lavoratori conseguente alla esposizione professionale agli insetticidi organofosforici.

Metodi: I campioni di frutta analizzati sono stati 199 nel 2008 e 203 nel 2009 così ripartiti: 12.68% mele, 11,.69% pere, 12.93% pesche, 6.46% uva, 5.72% fragole, 22.13% agrumi, 7.96% frutta esotica, etc.

Risultati: Nonostante un sostanziale decremento del numero di campioni di frutta senza residuo di pesticida (72.36% nel 2008 e 65.51% nel 2009), desta preoccupazione il numero di campioni con almeno un residuo di pesticida (21.10% nel 2008 e 22.6% l'anno successivo), ma soprattutto quelli con residui di due o più pesticidi che in un arco di tempo di 12 mesi si sono più che triplicati (3.01% nel 2008 e 9.85% nel 2009).

Discussione e Conclusioni: L'epidemiologia del fenomeno dell'uso di pesticidi in agricoltura deve essere considerato non esclusivamente sotto il profilo dei consumatori, bensì nell'ottica di un rischio professionale da parte degli agricoltori. Una tipologia di sostanze chimiche più frequentemente riscontrate, in particolare nella coltivazione di pesche, agrumi, uva e fragola sono Dimetoato e Clorpirifos, insetticidi, appartenenti alla categoria dei fosforganici, con una pericolosa azione neurotossica.

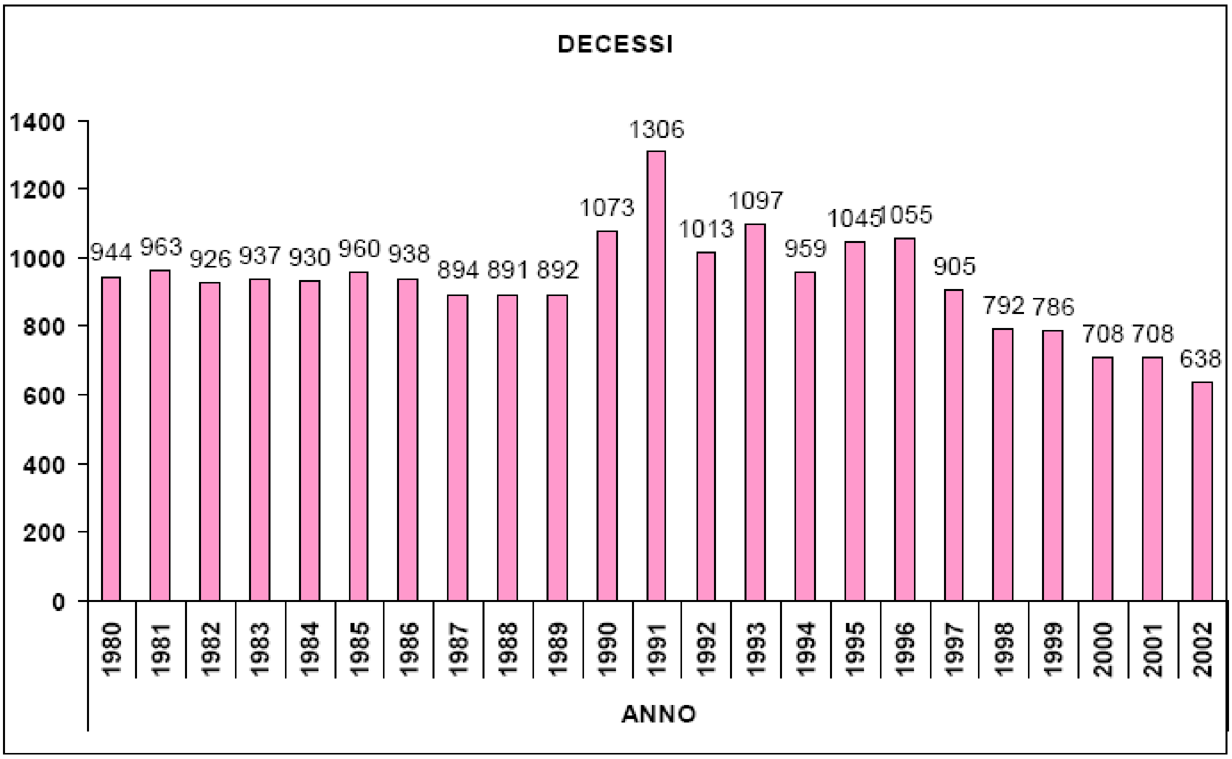
Background

Pesticides are a large number of substances used to protect crops from biotic and abiotic adversity (insects, mites, weeds seagrasses, shellfish, etc.). On the market there are about 700 active ingredients with 8000 preparations, in the composition of which are used other toxic substances such as solvents. Pesticides usually present a high intrinsic toxicity, since their primary function is to remove unwanted species. The compounds with poor selectivity of species can prove harmful also to humans.

There are many benefits arising from the use of different pesticides: social and economic benefits from increased agricultural production and public health: the eradication of the pathology of malaria is just one of many possible examples. Given these advantages, it is likewise important to take into account the undesirable effects on health related to workers' exposure to various substances, to the contamination of the environment, food and water by residues of pesticides and metabolites. Every year in our country multiple requests for assistance are received by poison control centers for poisoning by chemicals used in agriculture. In 1997 alone, the two poison centers in the capital have recorded more than 500 cases of poisoning.

From 1980 to 2002 deaths from poisoning were 21360 (figure 1).

Figure 1 - *Deaths from poisoning and toxic effects (ICD IX Rev: 960-989) in Italy (ISS, 2008)*



The pesticides most commonly used in Italy are organic phosphorus compounds and carbamates insecticides including, sulfur, polysulphide, sulphate of iron and copper compounds in fungicides, carbamates, thiocarbamates, triazines, dipiridilici and derivatives of carboxylic acids and carboxylic fenofenossi between herbicides, including coumarin rodenticides.

Regarding the safety aspects and the protection of agricultural workers'health, the legislative framework currently in force in our country fits that aspect well.

As can be seen from Legislative Decree 81/08, Italy complies with EU safety health principles, as it was with Legislative Decree 626/94.

Indeed, Law reserves a special attention to agricultural insurance, in that it has extended from 21 to 27 the number of occupational diseases under the last table of occupational diseases in agriculture.

It should also be reminded the obligation of the employer to produce a specific chemical risk assessment to be included in the Global Risk Assessment Document (DVR) of the company (1, 2, 3).

Lately, the focus has shifted to the supervision of the assessment system, that recent studies proved to be unsatisfactory (4), because most (68,3%) risk assessments are completely inadequate or wrong.

The agricultural worker is exposed to pesticides during different stages of the work-cycle, from the application of the pesticide on fruit and vegetable products to fruit harvests with a potential increase of the risk of exposure often related to the absent or inefficient training and information of workers (especially of seasonal ones).

As well as workers, even general population can be exposed to pesticides, both for their use at home (gardening) and for the ingestion of contaminated food and water, with effects dependent on the pesticide state (solid, liquid or gaseous), on the method of dosing and on the way of penetration into the body.

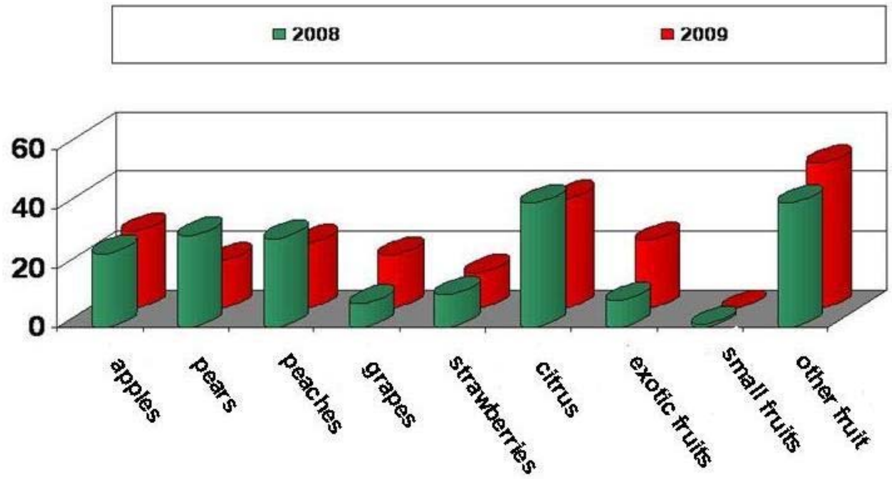
In our opinion it is useful to remember the size of the problem through an epidemiological analysis and make considerations for the treatment of a type of pesticide used most frequently, such as that of organo-phosphate.

Materials and Methods

The samples analyzed were 199 in 2008 and 203 in 2009.

The sample was distributed as follows: 12.68% apples, 11.69% pears, 12.93% peaches, 6.46% grapes, 5.72% strawberries, 22.13% citrus, 7.96% exotic fruits, etc.

Figure 2 - *Distribution of the samples in 2008 and 2009*



The methods used for sample analysis are those provided by the Italian National Institute of Health (ISS) in the manuals ISTISAN 1997/23 (multi-residue method for the analysis of pesticide residues in plant products) and 1997/24 (Guidelines for the application of good laboratory practice and the assurance and quality control in the analysis of pesticide residues).

These methods provide the homogenization of the sample, the extraction of the sample with ethyl acetate, the purification, and the analysis by gas chromatography with mass detection.

Extraction

The tested sample was first chopped, then homogenized "in toto" using shredder, or in case of quantities in excess of 2500 g using techniques of quartering (DM 20/12/1980).
The extraction of the active ingredients from the vegetable matrix was performed using ethyl acetate by means of extractor ASE and, where necessary, was used a purification with dual phase carbon cartridges and amines, eliminating or reducing in this way any interferents from the matrix.

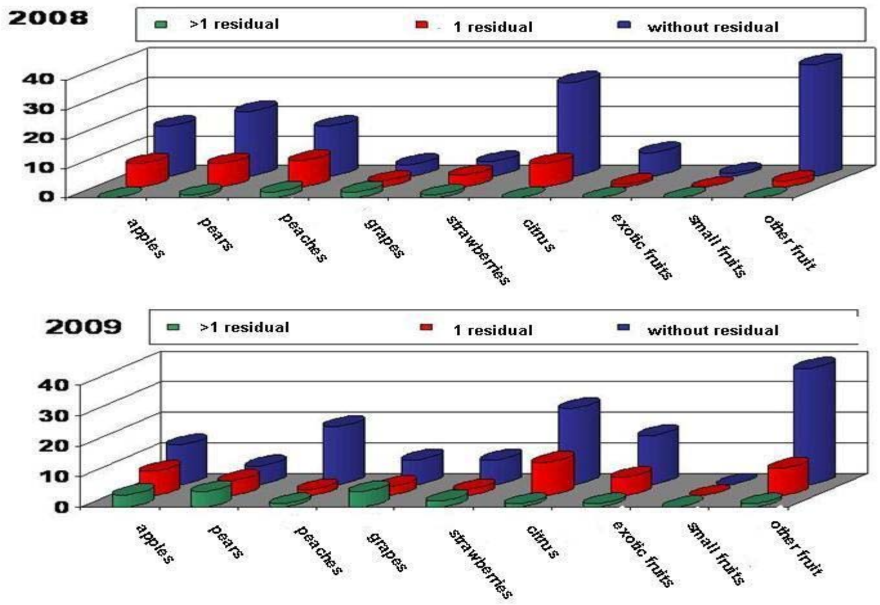
Purification on the cartridge
Activation: the cartridge was activated with the addition of about 1 g of anhydrous sodium sulfate in the upper part and then with the passage drop by drop into a sequence of 5 mL of acetonitrile-toluene mixture 3/1 and 5 mL of acetonitrile.
Passage of the sample and elution: the extract in acetyl acetate of the extraction was brought to dryness and taken up with 5 mL of acetonitrile.
The solution was then gradually loaded on the activated cartridge. The eluate was collected in a flak. After the loading phase elution was carried out with 20 mL of mixture acetonitrile / toluene 3/1. The eluate was collected in the same flask containing acetonitrile. Everything was brought to dryness and taken up with appropriate volume of ISTD (1-2 mL)

Analysis of samples
1 µl of sample was injected into the chromatograph as well as reconstituted and resumed after extraction or purification.
The chromatograms were acquired and verified the presence of any active principles in relation to the retention times and possibly confirmed by GC-MS.
Once confirmed the presence of active ingredients, their concentration was quantified using the response of standard of known concentration.

Qualitative confirmation of the analytes
The qualitative determination of analytes is performed with the quadrupole mass spectrometer.
The acquisition of chromatograms is performed on the GC/MS system operating under the following conditions:
Chromatographic system
Detector temperature 280 ° C
Injector temperature 250 ° C
Oven temperature 70 ° C x 2 minutes; 25 ° C / min (rate 1) for minute up to 200 ° C, 8 ° C / min rate 2 up to 280 ° C; to 280 ° C remains for 10 min
Column HP5MS (30mx 0.25 mm x 0.25 µm)
Splitless injector
MS detection
Acquisition in total ion current in the range 35-500 uma, with an source at impact of electrons (E +) applying a variable potential of at least 400 eV.

Results
The analyses conducted demonstrated that the samples of residue-free fruit pesticide analyzed in 2008 were 72.36% and were 65.51% in 2009.
Samples with at least one residual were 21.10% in 2008 and after 12 months they became 22.6%.
The fruit was analysed and found to be in the presence of more than one pesticide residue actually tripled with an incidence from 3.01% in 2008 to 9.85% the following year.

Figure 3 - *Distribution of the samples with 1 residual, >1 residual or without residual in 2008 and 2009.*



Samples of apples with residues of pesticides had an increase of 18% and about half of the apples tested in 2009 were positive. Followed by peaches.

A 25.80% value of pears with positive traces of residues in 2008 became more than half of the samples tested positive in 2009, namely 62.5%.

Concentrations allowed by law, however, were crossed in a very limited number of cases: 3.51% in 2008 and 2.95% in 2009.

Discussion and Conclusions

The organophosphorus insecticides are fat-soluble substances and therefore are easily absorbed by skin exposure, by inhalation, and by gastrointestinal tract (5, 6).

The substances known as organophosphorus listed above in the analysis are as follows: Dimethoate (for peaches and citrus fruits) and Chlorpyrifos (for grapes and strawberries).

The enzyme acetylcholinesterase represents the human biological target that is capable of inhibiting, obstructing its disposal, acetylcholine, a neurotransmitter in the central and peripheral nervous system of mammals, which binds to specific receptors on skeletal muscle and opens the membrane channels sodium allowing these ions to enter the muscle cell inducing contraction. At the level of synapses in the CNS it produces an excitatory stimulus type. Sometimes the link with the organophosphate acetylcholinesterase can be less, but acetylcholinesterase never undergoes a chemical change (aging) as a result of interaction with the pesticide, affecting the normal operation.

Literature describes the same action of inhibition by organophosphorus on an esterase, called neurotoxic esterase (7), whose gene is known, already isolated, with mechanism of action and substrate still unknown (8).

The symptoms can be attributed to the progressive accumulation of acetylcholine in the body and produces a muscarinic and nicotinic syndrome.

The muscarinic syndrome affects smooth muscle, vague and endocrine tissues and consists of sweating and salivation, nausea, vomiting and diarrhea. The effects on the heart are bradycardia and acute pulmonary oedema.

The nicotinic syndrome, however, concerns the striated muscles and preganglionic nerve fibers. It consists of fasciculations, contractures and muscle spasms, and can result in cardiovascular tachycardia and hypertension.

The amount of symptomatology varies depending on the level of exposure.

At the neurological level a mental and a motor slowdown and disturbance in attention and concentration or real convulsions can occur.
Prolonged exposure may be associated with generalized myopathy with necrotic lesions and cyto-histological changes in the endplate citostruttura (9).
Among cases reported in literature, there is the possibility of acute pancreatitis mediated by an increase in intraductal pressure (10, 11, 12, 13, 14) and a late symptom, lasting from one to four days after exposure, defined intermediate syndrome (15, 16).

The diagnosis is based on a determination of pseudocholinesterase (PCHE) and acetylcholinesterase (AChE) in the erythrocytes and in the plasma (for diagnostic confirmation). This is especially true in chronic intoxication, or during long exposures to lower concentrations, which commonly occurs in the workplace (17).

The therapy in case of contact, more frequent in the workplace, requires the washing of skin and hair with water and soap. Enteral exposure resolves within 60 minutes with gastric lavage followed by administration of activated charcoal powder.
The antidote used in severe acute poisoning is atropine at a dose of 2-4 mg ev/15', which antagonizes the action of the pesticide, especially in the respiratory tract.
Pralidoxime, which reactivates acetylcholinesterase, is effective primarily for the symptoms of nicotine (18, 19, 20).

A large number of poisoning are reported in the developing countries (21, 22) and the reasons are the lack of regulation and the useless protection of workers health. It should necessarily start from risk assessment, inspired by prevention criteria, divided in the four phases for the identification of risk agents (hazard identification) at first, and later in the determination of the correlation between the quantity of the agent and the biological response of the organism (dose-response assessment), according to the always valid model for risk assessment proposed by the National Academy of Science (1983) (23), followed by an exposure assessment and risk characterization to test the likelihood and severity of damage to the health in those exposed.
Research and analysis of risks and potential harms on humans become essential requirements for any management model (24) which has the objective of safety of person and worker.

In Italy occupational physicians take care of the health surveillance of exposed workers through mandatory and periodic checkups, before a specific job and after being exposed.
The biological monitoring of workers exposed to organophosphate is implemented by measurement of erythrocyte cholinesterase (synthesized by the nervous system, by the neuromuscular junctions of striated muscle, by the red blood cells and by the adrenal gland) and by plasma cholinesterase or pseudocholinesterase (which is in plasma, myocardium, smooth muscles, digestive mucosa and skin).
Other effect indicators for organochlorine insecticides are the dosage of D-glucaric acid and 6-beta-hydroxycortisol in urine.
The American Conference of Industrial Hygienists reports a 70% reduction in RBC cholinesterase from baseline individual values as biological index of exposure to organophosphorus esters.
Dosing with neurotoxic esterase permits to evaluate the delayed effects of organophosphorus esters on the peripheral nervous system, the dosage of cholinesterase following exposure to carbamates is less reliable as an indicator of effect, being the link with the insecticide rapidly reversible.
We hope for a better cooperation of the Employer and the Service of Prevention and Protection with the occupational physician for the protection of the health and safety of workers exposed to the pesticides risk, also through risk assessment, the choice of personal protective equipment as well as information and training courses held in accordance with the current Laws.

References

1. Hardman JG, Limbird LE, Goodman Gilman A. Le basi farmacologiche della terapia, McGraw-Hill, Milano, 2003.

2. D. lgs n. 25 del 2 febbraio 2002 in attuazione della direttiva 98/24/CE – G. U. n. 57 del 8 marzo 2002 – Suppl. Ord. n. 40.

3. Artt. 17 co. 1 lettera a) e 28 del D. lgs n. 81 del 9 aprile 2008 – G. U. n. 101 del 30 aprile 2008 Suppl. Ord. n. 108.

4. Sciarra G, Aprea MC, Cardelli D, at al. Il documento di valutazione del rischio chimico: esperienze nelle piccole imprese. Giornale Italiano di Medicina del Lavoro 2010; 32 (4): 125 – 128.

5. HSDB: Hazardous Substances Data Bank. National Library of Medicine, Bethesda, MD (Internet Version), Micromedex, Inc, Englewood, CO, 2000.

6. RTECS: Registry of Toxic Effects of Chemical Substances. National Institute for Occupational Safety and
Health, Cincinnati, OH (Internet Version). Micromedex, Inc, Englewood, CO, 2000.

7. Johnson MK. Symposium introduction: retrospect and prospects for neuropathy target esterase (NTE) and the delayed polyneuropathy (OPIDP) induced by some organophosphorus esters. Chem. Biol. Interact. 1993; 87: 339-346.

8. Glynn P. Neural development and neurodegeneration: two faces of neuropathy target esterase. Prog. Neurobiol., 2000; 61: 61-74.

9. Dettbarn WD. Pesticide induced muscle necrosis: mechanisms and prevention. Fundam. Appl. Toxicol. 1984; 4: S18-S26.

10. Betrosian A, Balla M, Kafiri G, et al: Multiple systems organ failure from organophosphate poisoning. Clin Toxicol 1995; 33: 257-260.

11. Yamashita M, Yamashita M, Tanaka J, et al. Human mortality in organophosphate poisonings. Vet Human Toxicol 1997; 39: 84-85.

12. Zoppellari R, Borron SW, Chieregato A, et al. Isofenphos poisoning: Prolonged intoxication after intramuscular injection. Clin Toxicol 1997; 35: 401-404.

13. Zatelli R, Zoppellari R, Mantovani G, et al. Severe poisoning by organophosphate methidathion injection: clinical and kinetic aspects (Abstract). EAPCCT 15th Congress, Istanbul, Turkey, 1992.

14. Senanayake N, Sanmuganathan PS. Extrapyramidal manifestations complicating organophosphorous insecticide poisoning. Human Exp Toxicol 1995; 14: 600-614.

15. Marrs TC. Organophosphate poisoning. Pharmacol. Ther. 199; 58: 51-66.

16. De Bleecker JL. The intermediate sindrome in organophosphorus poisoning: an overview of experimental and clinical observations. J. Toxicol. 1995; 33: 683-686.

17. Storm JE, Rozman KK, Doull J. Occupational exposure limits for 3 organophosphate pesticides based on inhibition of red blood cell acetylcholinesterase. Toxicology 2000; 150: 1-29.

18. Haddad LM, Winchester JF. Clinical Management of Poisoning and Drug Overdose, 2nd ed. WB Saunders Company, Philadelphia, PA, 1990.

19. Karalliedde L, Senanayake N. Acute organophosphorus insecticide poisoning in Sri Lanka. Forens Sci
Internat 1988; 36: 97-100.

20. Barceloux D, McGuigan M, Hartigan-Go K. Position statement: cathartics. American Academy of Clinical
Toxicology; European Association of Poisons Centres and Clinical Toxicologists. Clin Toxicol 1997; 35: 743-752.

21. Bardin PG, Van Eeden SF, Moolman JA, at al. Organophosphate and carbamate poisoning. Arch. Intern. Med. 1994; 154: 1433-1441.

22. Landrigan PJ, Claudio L, McConnell R. Pesticides. In: Environmental Toxicants: Human Exposures and Their Health effects, Lippman, New York, 2000.

23. Cottica D, Grignani E. Valutazione dell'esposizione ad agenti chimici: algoritmi e misurazioni, vantaggi e criticità. G Ital Med Lav Erg 2010; 32 (4Suppl.): 113-116.

24. Gino G. Aspetti metodologici e normativi per l'analisi dei Rischi Chimici Occupazionali. G Ital Med Lav Erg 2010; 32 (4Suppl.) 108-112.

Corresponding Author: Serafino Ricci
Department of Anatomical, Histological, Forensic Medicine and Orthopedic Sciences,
"Sapienza" University of Rome
e-mail: info@preventionandresearch.com

Autore di riferimento: Serafino Ricci
Dipartimento di Scienze Anatomiche, Istologiche, Medico Legali e dell'Apparato Locomotore,
"Sapienza" Università di Roma
e-mail: info@preventionandresearch.com