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Chemical Control of Spiders and Scorpions in Urban Areas

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1. Introduction

The chemical control of invertebrates that are regarded as pests has always been governed by the development of molecules with insects as their main target. The group of arachnids, which comprise spiders and scorpions among other groups, has received little attention, with the exception of mites which are considered to be agricultural pests. In this chapter, we make a critical review of the chemical strategies used to control synanthropic (ecologically associated with humans) spiders and scorpions that are considered public health problems and also make suggestions regarding future lines of research in this area.

2. Biology of spiders and scorpions – basic aspects

Spiders (Araneae) and scorpions (Scorpiones) constitute, within the Orders of Class Arachnida - together with mites (Acari), - the pests of greatest economic and public health concern. The other orders of arachnids – Schizomida, Thelyphonida, Amblypygi, Palpigradi, Ricinulei, Opiliones, Solifuga and Pseudoscorpiones – representing animals that are mainly found in the natural environment and do not cause any significant economic damage or health problems to humans.

2.1 Biology of spiders

Spiders constitute a diversified group of organisms with currently 42,473 officially recognized species, grouped into 110 families [1]. Spiders are widespread throughout the world and have conquered all of the ecological environments except for the air and oceans. Big tarantulas can have a large body length (*Theraphosa blondi* from Amazonia can have a leg span of up to 28 cm) but most spiders are small (with a body length of 2-10 mm) [2]. Practically all the spiders capture prey for food and the main prey group for most species consists of insects, although a wide range of invertebrates including spiders (Mimetidae spiders specialized in hunting spiders) and even small vertebrates are included [2]. Spiders are beneficial to man in various ways, and generally act as a form of insect control in the natural ecosystem [3]. Their practical use as possible agents of biological control has been confirmed in several cases [4]. Many species of tarantulas are considered pets [5]. Among

the different species of spiders, only a few genera are regarded as a risk to human or animal health.

Spiders (Figure 1) have the body divided into two main regions, the prosoma or cephalothorax and the opisthosoma or abdomen. The prosoma serves as the attachment site for six pairs of extremities: one pair of biting chelicerae, one pair of leg-like pedipalps and four pairs of walking legs. The opisthosoma chiefly carries out vegetative tasks: digestion, circulation, respiration, excretion, reproduction and silk production. In contrast to the prosoma which is hard, the abdomen is rather soft and saclike; the spinnerets are located at its posterior end.

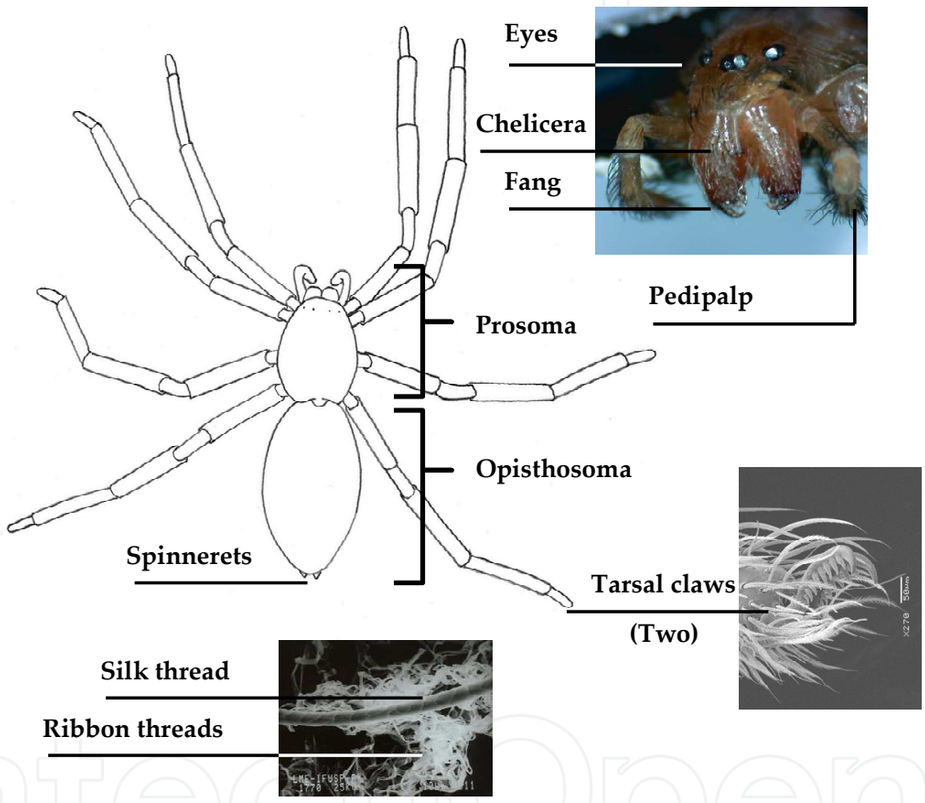


Fig. 1. External appearance of a spider´s body, showing some anatomic details of the brown spider *Loxosceles intermedia.*

Almost all species of spider use venom stored in venom glands which open at the tips of the cheliceral fangs, where it is injected into their prey. Spider venom may contain many different substances. It is mainly a mixture of large neurotoxic polypeptides (molecular weight 5,000–13,000) and smaller biogenic amines and aminoacids; proteolytic enzymes may also be present [2]. Venom composition is highly species-specific and depends on many factors including sex, nutrition, natural habitat, climate, etc. [6]**.** Spiders have been held culpable as a cause of human suffering for centuries, but there are few species in the world that cause medically significant envenomation [7] (Table 2). In several larger species (*Phoneutria* spp., *Atrax* spp.), the venom may have evolved for defense against mammals

(indicated by immediate painful bite due to venom components or to mechanical damage inflicted by large fangs). However, in recluse spiders, an initially painless bite at fang penetration with effects only manifesting hours later must be perceived as a mere evolutionary vagary of venom chemistry that such toxic components have effects on humans [8]. Most other spiders involved in bites that have been verified only have minor, transient effects. Several species of tarantulas have urticating hairs that can cause some health problems [5, 7, 8, 9]. Many spiders which have been blamed for causing medical ailments, have been elevated to medical significance as a result of circumstantial evidence, poor reporting, and repetitive citation in the literature; several species have been shown to be harmless when alleged bites in humans have been subjected to more stringent scientific evidence [7, 8].

Spiders are not the only organisms that spin webs but the importance and various ways that spiders make use of webs has no parallel in any other group of animals [2]. Currently, webs similar to those of spiders can be produced through synthetic means and a wide range of technological applications are envisaged in the future [10]. The webs are only produced in the spinnerets located at the posterior end of the abdomen. Most species of spiders leave a dragline of thread secreted from its spinnerets which is fixed to the substrate at regular intervals and can serve as a safety line or as a means of intraspecific communication [2]. Of the venomous spiders which are found in the urban environment, only *Loxosceles* species do not secrete a dragline. The spiders that spin orbicular webs are not included in the species that are confirmed to be of risk to human health [8]. Spiders can have two or three small claws, called tarsal claws, at the extreme ends of their legs (Figure 1). Some spiders have dense cushions of extremely fine hair lying directly under the claws, called claw tufts [2]. All spiders that have claw tufts on the tips of their legs can walk with ease on smooth vertical walls, and even on window panes [2]. Spiders without claw tufts such as *Loxosceles* and *Latrodectus* depend on substrates as rough surfaces where the claws can be given support. *Phoneutria* spiders manage to climb up smooth substrates, in spite of the considerable size of the adult spiders. Spiders employ a hydraulic mechanism mediated by the prosoma to assist the movement of its legs and compared to insects, have a much lower ratio of muscles to body volume [2]. Owing to this particular feature spiders are very sensitive to water loss, as the loss of body fluid causes serious locomotor difficulties. The spiders that records periods without food or water are included on the *Loxosceles* genus, which can resist more than one year without food or water. At the same time, most spiders given the chance to obtain water, can survive periods of several months without food. The use of pesticides can thus significantly reduce the availability of prey but this alone will not lead to the deaths of spiders. Some studies have shown that spiders can be fed on insects killed by pyrethroids, without apparently being affected [11, 12]. The pedipalps (Figure 1) of adult male spiders are copulatory organs. In general, male spiders are smaller than females and have a shorter life cycle. In black widow spiders, for example, the weight of the small males represents only 1-2% of the female mass. In contrast to females, most male spiders change radically their habits after their final molt. They leave their retreats and webs and start searching for females; often they no longer even catch prey. Due to the risk of intraspecific predation, spiders have a specific courtship behavior that generally precedes mating. The common belief that male spiders are eaten by the females during or after copulation only applies to a few species. Fertilized females lay eggs and build an egg case (also know as egg sac or cocoon) made of silk [2]. Some spiders can build several egg cases before they die. Large spiders may have cocoons with thousands of eggs. Generally there is no maternal care after

the spiderlings leave the egg sac. The young spiders molt several times until they become adults. With most Araneomorphae, no further ecdysis occur after sexual maturity but in the case of Mygalomorphae molts continue to occur in the adult stage [5]. The length of intermolt intervals depends on nutritional conditions and the number of molts on the ultimate body size. Small spiders only need a few molts (about five) whereas large spiders pass through about ten molts before reaching the adult stage. Small males achieve maturity with one or two fewer molts than large females [2].

2.2 Biology of scorpions

Scorpions originated approximately 400 millions years ago and were among the first arthropods to occupy terrestrial environments. Today they can be found worldwide, except in Antarctica, and the presence of some species in urban areas is well-known [13]. Scorpions are commonly thought of as desert creatures, but in fact, they occur in many other habitats, including grasslands and savannahs, deciduous forests, mountain pine forests, intertidal zones, rain forests and caves. A matter of historical curiosity is the fact that nearly 2,000 years ago, live scorpions were used by the Parthians as military weapons in the form of "scorpion bombs". Terracotta pots have been found at the desert fortress of Hatra near modern Mosul, Iraq, where scorpion bombs were used to successfully repulse Roman besiegers in AD198 [14]. Approximately 1,500 species of scorpions have been described in the world, which are currently divided into 18 families [15]. There is considerable disagreement about the best way to classify scorpions [15, 16]. A few species possess potent toxins capable of killing human beings (Table 1). All scorpion species with highly potent, mammal-specific neurotoxins, except for Scorpionidae, belong to the family Buthidae, including the genera *Androctonus*, *Buthacus*, *Buthus*, *Centruroides*, *Leiurus*, *Mesobuthus*, *Parabuthus*, and *Tityus* [13, 17, 18]. However, the size of the scorpion seems to play an important part: for the genera considered as dangerous (especially *Tityus* and *Leiurus*), species exceeding 5 cm must be regarded as potentially dangerous for humans, even if they do not appear in Table 1 [18]. Buthidae is the largest family of scorpions: Fet & Lowe [19] listed 73 genera and 529 species in the "Catalog of Scorpions of the World", and it is likely that many more species are still to be discovered. This group is ecologically diverse and became widespread across the globe [20].

Like all arachnids, scorpions have mouthparts called chelicerae, a pair of pedipalps, and four pairs of legs. The pincer-like pedipalps are used primarily for capturing prey and defense, but are also covered with various types of sensory hairs. The body is divided into two main regions, the cephalothorax and the abdomen (Figure 2). The cephalothorax is covered by a carapace that usually bears a pair of median eyes and 2 to 5 pairs of lateral eyes at its front corners. The abdomen consists of 12 distinct segments, with the last five forming the metasoma which most people refer to as the "tail". At the end of the abdomen is the telson, which is a bulb-shaped structure containing the venom glands and a sharp, curved stinger to deliver venom (Figure 2). Scorpions experience great difficulty in climbing up smooth surfaces and one of the recommendations for their control is to cover the foundations of buildings with surfaces that are metallic or made of other smooth materials which can prevent the creatures from ascending. Inside the dwellings, the furniture, such as the beds, should have smooth bases and be kept away from walls to deny the scorpions access. On its underside, the scorpion bears a pair of unique comb-like sense organs called the pectins (Figure 2); these are usually larger and bear more teeth in the male and are used

to sense the texture and vibration of surfaces. They also serve as chemoreceptors (chemical sensors) to detect pheromones (communication chemicals) [13, 21]. By means of their pectins, scorpions can detect various kinds of pesticide applied to the substrate, as will be seen later in this chapter, and are able to take action to avoid molecules, particularly non-microencapsulated formulas.

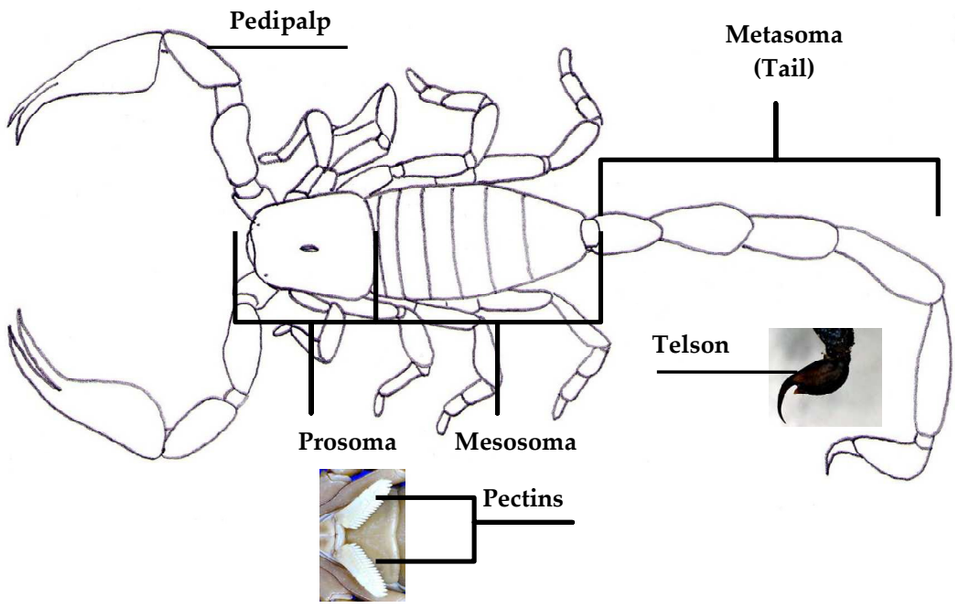


Fig. 2. External appearance of a scorpion's body, showing some anatomic details of *Tityus costatus*.

Scorpions fluoresce or glow strongly under ultra-violet light [13, 21] so they are easy to find with the aid of a black light during the night. Currently UV LED models are available, and the night is the best time for scorpion hunting as they are generally more active in low luminosity. All the species are predatory creatures that feed on a variety of insects, spiders, centipedes and other scorpions, thus, areas with an abundance of prey, such as cockroaches, can expect to have high-density levels of scorpions. The larger scorpions occasionally feed on vertebrates, such as small lizards, snakes, and mice. Most scorpions are ambush predators who detect prey when it comes within reach. As with many predators, scorpions tend to forage in distinct and separate territories, returning to the same area each night. They may enter homes and buildings when their territory has been disrupted by construction, tree removal or floods, etc. Although they are equipped with venom for defense and prey acquisition, scorpions themselves fall prey to many types of creatures, such as centipedes, tarantulas, insectivorous lizards, snakes, birds (owls and chicken), and mammals (including shrews, grasshopper mice, and bats) [13]. Most scorpions are active at night, and spend their days where it is cool and moist under rocks, wood, tree bark or in burrows. Although scorpions have been seen drinking directly from water reservoirs, they derive most of their water from their food, but this varies according to species.

Scorpions have a complex mating ritual in which the male uses his pedipalps to grasp the female's pedipalps. The male then leads her in a "courtship dance". The details of courtship vary from species to species. The sperm from the male is contained within a structure called

Species and Distribution	
Androctonus	
A. aeneas	Africa, North of Sahara, Saharan oases and African Sahel
A. australis	From Algeria to Egypt, Saharan oases
A. crassicauda	From North Africa to Saudi Arabia and Turkey
A. mauretanicus	Morocco
A. hoggarensis	Saharan mountains
Hottentota	
H. franzwerneri	Morocco
H. tamulus	India
Buthus	
B. occitanus	East Mediterranean basin and African Sahel
Leiurus	
L. quinquestriatus	Africa, Middle-East
Parabuthus	
P. granulatus	South Africa
P. transvaalicus	South Africa, Zimbabwe
P. villosus	South Africa, Namibia
P. liosoma	Saudi Arabia
Hemiscorpius	
H. lepturus	Iran, Iraq
Mesobuthus	
M eupeus	Turkey, Caucasus, Iran, Afghanistan
Centruroides	
C. exilicauda	South of the United States
C. infamatus	South of the United States, Mexico
C. elegans	Mexico
C. noxius	Mexico
C. suffuses	Mexico
C. limpidus	Mexico
C. gracilis	Colombia
Tityus	
T. pachyurus	Colombia
T. trinitatis	Trinitad
T. discrepans	Amazonian basin
T. cambridgei	Amazonian basin
T. caripitensis	Venezuela
T. surorientalis	Venezuela
T. arellanoparrai	Venezuela
T. bahiensis	Brazil
T. brazilae	Brazil
T. serrulatus	Brazil
T. stigmurus	Brazil
T. trivittatus	Argentina

Table 1. Distribution of a selection of medically important scorpion species based on Keegan [17] and Chippaux and Goyffon [18].

a spermatophore, which is deposited by the male on a surface over which the female is dragged. The male sweeps his pectins over the ground surface to help locate a suitable place to deposit his spermatophore. The female draws the sperm into her genital pore, which is located near the front ventral side of her abdomen. However, several species, like *Tityus serrulatus*, are represented only by females and reproduce by parthenogenesis. This reproductive strategy undoubtedly greatly increases the opportunities for dispersion and invasion of anthropogenically-impacted habitats. The gestation period is long, from several months to over a year, depending on the species. The young develop as embryos in the female. The young are born live and ascend their mother's back. Generally, a female gives birth to about 15-35 young [13]. They remain on her back until they molt for the first time, or even for some more weeks. Typically five or six molts over two to six years are required for the scorpion to reach maturity. The average scorpion probably lives for three to five years, but some species may live up to 25 years. A few scorpions exhibit social behavior that goes beyond that of the mother-young relationship, such as forming over-wintering aggregations, colonial burrowing, and perhaps even living in extended family groups that share burrows and food [13, 21]. All scorpions possess venom and can sting, but their natural tendency in a confrontation situation is to hide or attempt to escape. As they are able to control the venom flow, some sting incidents are venomless or only mild envenomations. In view of the medical and biological importance of scorpions, it is unfortunate that we are still relatively ignorant of their characteristics. Obviously, more research needs to be conducted on almost all aspects of scorpion biology. For example, we know very little about the natural history or field behavior of most of the deadly species [21].

3. Control of spiders and scorpions - history, context and key initiatives

The organochlorine pesticides were used extensively until the 1970s to combat invertebrate pests. In the 1970s its use was restricted in the United States and later in other countries, as a consequence of its power to bioaccumulate in the environment, causing major environmental impacts. Organochlorines were classified as Persistent Organic Pollutants (POPs), which led to the development and use of other classes of compounds for pest control. So part of the literature until the 1970s lists organochlorine pesticides among the products indicated for chemical control, but other molecules in the following period were tested as possible agents of pest control. The Stockholm Convention on Persistent Organic Pollutants, a global treaty focused on POPs, adopted in 2001 and entered into force in 2004, requires parties to take actions to eliminate or reduce the release of POPs into the environment. The mandate to draw up the Treaty clearly stated that none of its measures should adversely affect public health; therefore, the use of DDT in disease vector control was given special status, as this is considered an acceptable purpose. Nevertheless, the Treaty imposes certain requirements on parties that use DDT [22]. It was observed a general shift from organophosphorus to carbamate insecticides; then a shift to pyrethroids, starting in the 1980s [22].

In this chapter we reviewed information about species of spiders and scorpions that are pests of public health interest, as well as bioassays of pesticides on these target species and field tested control initiatives. We searched for books, and papers in peer reviewed journals through databases (Medline and Scielo mainly) and the bibliographical references contained therein, as well as official documents of the WHO and manuals or bulletins made available online by Universities or Governments. A major obstacle was the almost total lack of

bioassays published in peer reviewed journals for some species. Therefore, several documents relating to congress presentations, masters and doctoral thesis and other materials, were included when considered relevant. We defined the magnitude of the problem, mainly related to public health, and then focused on selected species.

3.1 Spiders - basic epidemiologic data and main control efforts

Spiders arouse feelings of aversion in people and of all the invertebrates constitute one of the main causes of phobic reactions [2]. A spider bite often inspires dread and is associated with a good deal of mythology resulting from the media attention that is given to the rare cases of fatalities [7, 8]. There is usually an extremely low degree of tolerance among people of spiders in dwellings, even of those that do not pose any risk to human health or are not very aggressive. In general, spiders around the world are erroneously blamed for causing dermonecrotic and other lesions when the evidence points in many other directions. [7, 8]. Such misdiagnoses can lead to serious medical complications if the correct diagnosis is delayed or the treatment is inappropriate or ineffective [7, 8]. Since most studies are retrospective and few data on spider bites have been verified, the literature on spider envenomation is often based on inference from animal models in toxicology; circumstantial evidence; poorly designed or otherwise inferior clinical studies; and unfortunately, considerable hyperbole [8]. There are no international registries for spider bites, but the American Association of Poison Control Centers (AAPCC), the Australian Poison Information Center (PIC), and several academic and governmental health centers in Australia, Brazil and Chile for example, report descriptive data. The spiders whose venom is harmful to humans include the *Phoneutria*, *Atrax*, *Latrodectus* and *Loxosceles* genera (Table 2).

Spider taxa	Main active components of venom	Symptoms after bite
"Widow" spiders of the genus *Latrodectus* (Theridiidae)	Alpha-latrotoxin, protein neurotoxin, causes exhaustive release of neuromediators	Pain lasting from hours to days with potentially lethal nonspecific systemic effects
"Brown" or "recluse" spiders of the genus *Loxosceles* (Sicariidae)	Enzyme phospholipase D (sphingomyelinase D), necrotic toxin	Skin injuries of different severity from slight irritation to serious ulcers and possible development of systemic hemolysis leading to death
"Armed" spiders of the genus *Phoneutria* (Ctenidae)	Peptide neurotoxins affecting sodium channels	Pain at site of sting, priapism, possible life-threatening hypotension
Australian "funnel-web"spiders of genera *Atrax* and *Hadronyche* (Hexathelidae)	Delta-atracotoxins, peptide neurotoxins affecting sodium channels	Local and systemic effects of different severity: pain at site of sting, paresthesia, muscular spasm, general excitation, hypertension, disturbance of cardiac rhythm (arrhythmia), coma

Table 2. Spiders with venoms that constitute significant threat for human health. Based on Vassilevski *et al.* [6].

In fact, these four genera comprise the only spiders whose toxicity has been proved. Many other species have been linked to cases of poisoning (e.g. *Tegenaria agrestis*, *Cheiracanthium* spp., *Lampona* spp., *Steatoda* spp., Lycosidae) but in every case with proof that is not convincing and in most cases has been subsequently refuted [8]. For example, in South America, experimentally induced necrosis and poor clinical reporting have led to harmless wolf spiders (family Lycosidae) to be blamed for causing skin lesions [23]. Wolf spider antivenin was developed and used for decades. Subsequent tracking of 515 documented wolf-spider bites in humans with no necrosis showed the attribution to be erroneous and the treatment unwarranted [23]. In another example, largely on the basis of scraps of unsubstantiated evidence, white-tailed spiders (*Lampona* spp.) were erroneously assumed to be the etiologic agents of human dermonecrosis in Australia. This led to hyperbole in the popular and medical press, creating an urban myth [24]. Several American states report dozens to hundreds of loxoscelism diagnoses annually, even though brown recluse spiders are extremely rare or have never been found in those states or regions [8]. It is important to determine what constitutes reliable evidence in clinical toxinology; a definite spider bite case requires all the following criteria to be met: (*a*) clinical effects at the time of the bite; (*b*) the spider being caught immediately at the time of the bite; and (*c*) expert identification of the spider [7, 8, 25].

With regard to the chemical control of spiders, on the basis of the review of the literature, it is evident that a large number of the suggestions about the molecules that should be used, as well as the forms of application, are based on subjective experience in the field, on the recommendations of the manufacturers or on methods designed to insect control. Much less frequent are bioassays carefully carried out with spiders, or field trials of these products and their methods of application [11]. Spiders are not only considered targets of pest control programs. They can be used for the control of insects in integrated agricultural pest management programs [3, 26, 27]. Most of the studies on the susceptibility of spiders to pesticides are based on an evaluation of agricultural products used in the field. Laboratory studies have demonstrated that broad-spectrum insecticides such as organophosphates, carbamates and organochlorines have significant lethal effects on spiders in general [28]. In Israel, laboratory residue studies, showed that the organophosphate chlorpyrifos was highly toxic to *Cheiracanthium mildei*, a hunting spider known to occur in large numbers in citrus orchards [29], whereas natural products (i.e. *Bacillus thuringiensis* and neem extracts) were virtually non-toxic to spiders [30]. Fungicides have been shown to have little or no toxicity against spiders [31]. The effects of exposure to a single sublethal dose of the pesticide malathion on the mating behavior of the lycosid *Rabidosa rabida* were such that it was severely disrupted and resulted in the most heavily dosed males being killed by the females without achieving copulation. The spiders were tested in combinations where one or both sexes were exposed to the insecticide. The data indicate that while there was no effect on the patterning of courtship behavior, the control males initiated courtship more rapidly than those that had been exposed [32].There was also an alteration in the walking patterns, generally leading to an increase in locomotion [33]. The insect growth regulators tebufenozide and fenoxycarb are safe for spiders and predatory mites [34]. Field experiments have revealed that some species of spiders are more sensitive to insecticides than others [35]. Among many factors influencing their susceptibility, foraging mode seems to play an important role. Aspects of foraging mode that appear to be relevant are whether the spider is diurnal or nocturnal, a hunter or a web-maker [35]. Another source of data on the effects of pesticides on spiders has emerged from the mosquito management campaigns

both in the United States and globally, for the effective control of the mosquito vectors of the West Nile virus and many other diseases. Davis and Peterson [36] carried out studies with adulticides (permethrin and d-phenothrin) and larvicides (*Bacillus thuringiensis israelensis* and methoprene) on non-target aquatic and terrestrial arthropods (including spiders) after single or multiple/repeated applications. Nearly all the responses evaluated registered few, if any, deleterious effects from the application of the insecticide.

In this Chapter, different categories will be presented and adopted concerning the situations with varying degrees of relevance and urgency in the need to control spider populations. Some genera, such as *Latrodectus* and *Phoneutria*, can be included in more than one category, depending on the species involved and the situation under consideration:

1. The presence of species of spiders representing a potential risk to human health and able to effectively establish populations inside dwellings or in the peridomicile for several generations. Also being capable of spreading out to neighboring areas, with greater or less speed, depending on their method of dispersion and reproductive capacity. They thus have a real potential to become a public health hazard. Currently, several species of the *Loxosceles* genus are those that best fit this citerion. They may prefer the intradomicile or peridomicile areas, depending on the species involved, and are regarded as significant public health problems, particularly in Chile and Brazil. Some species of the *Latrodectus* genus are mainly concentrated in the peridomicile area while others conform to the pattern of the item **5** below.
2. The presence of species which pose a risk to human health but become much more frequent at certain specific times of the year. Usually in the reproductive season or the warmer periods, when there is an increased mobility and they can occasionally invade dwellings, though without normally establishing permanent intradomiciliar populations. One example being the armed spiders *Phoneutria nigriventer*, which generally involve attacks caused by males wandering about in search of females during the reproductive season [37].
3. The presence of species that do not represent a significant risk to human health and which can occasionally be found in dwellings and even establish stable populations. The spiders that are sometimes found in the dwellings form a part of the fauna of invertebrates in the peridomicile or surroundings of the dwelling, usually in areas of natural or disturbed vegetation nearby. Mention should be made of the cursorial spiders of the families Lycosidae (wolf spiders), Salticidae (jumping spiders) and also the males of the Mygalomorphs (tarantulas). These spiders, especially those of greatest size, can cause considerable discomfort to the residents and even lead to cases of bites, though without serious implications for human health. Other spiders occupy the intradomiciliar region on a permanent basis, like the cosmopolitan *Achaearanea tepidariorum*, which spins cobwebs in corners of rooms, windows and similar places. The southern house spider *Kukulcania hibernalis* is found in many places in the world and can spin webs in various items of constructions. The pholcids or daddy longlegs spiders, like *Pholcus phalangioides*, are also common in various parts of the world, as well as *Metaltella simoni* (Amaurobiidae) Residents of dwellings can be made uncomfortable by the presence of these spiders, particularly on account of their visible webs and they can become the target of control measures.
4. In some specific industrial or business areas, a situation like that of items **1**, **2** or **3** could prevail and there is a low tolerance level to the presence of spiders on the part of clients, employees or even by the quality control standards. This is the case with shopping

centers, and factories which have strict standards of hygiene, like the food industry and others. There is a need to carry out effective control measures more often, regardless of the risk of injuries from bites - this is usually only done by pest control companies. A lot of spiders that spin webs, like *K. hibernalis* and *A. tepidariorum* can be included as targets in this category, together with many araneids with orbicular webs and also other pholcids and theridiids. These webs can accumulate detritus and periodically it maybe necessary to carry out a mechanical removal. A novel case that involved industrial products was found in the car industry. In 2011, Mazda will be recalling 65,000 vehicles in the United States, Canada and Mexico so that they can be fitted with special screens to keep out spiders. There is concern that the webs could block the air flow in the fuel tank vent and this could cause the tank to leak or even catch fire. The spider involved was identified as the yellow sac spider *Cheiracanthium inclusum* [38].

5. Some venomous spiders that are found in cultivars in nature, can travel together with the products that have been gathered or harvested and then be introduced into private dwellings and commercial premises in the country of origin or even in other countries. Ctenids such as *P. nigriventer* occur in banana plantations in Brazil. The widow *Latrodectus hesperus* have become a pest due to their unwanted presence in grape clusters in the table grape vineyards of San Joaquim Valley, California, USA [39]. In 2001, New Zealand banned the imports of California table grapes after four *L. hesperus* individuals were found in table grape clusters [40].
6. Recent papers have drawn attention to the potential occupational and contact allergies caused by spiders such as *Tegenaria domestica* [41, 42], and even to a new asthma-causing allergen from the cellar spider *Holocnemus pluchei* [43].

In this Chapter we will focus on the *Loxosceles* and *Latrodectus* genera (which fit into item **1** in our classification), because of their medical importance in several parts of the world, the synanthropy of various species of the genera and from the literature available on their chemical and other control measures. *Phoneutria* will not be included, as it is in the items **2** and **5** of our classification. The *Atrax* genus will not be included because they are not common in urban areas and severe envenoming is rare with this species with only 5-10 cases recorded annually, largely confined to a restricted region in Eastern Australia [8].

Latrodectus – The species of the genus *Latrodectus* (Theridiidae) are commonly known as "widow" spiders. The name of the black widow spider, *Latrodectus mactans*, is a combination of Latin and Greek, meaning "deadly biting robber". European authors have documented widow spider bites for over 2000 years [44]. From the 13th to 17th centuries in Europe, the tarantella was danced to ward off the effects of spider envenomation. The spider involved was almost certainly the endemic widow spider, *L. tredecimguttatus* [44]. In the late 1800s, American and Australian entomologists linked these spiders to severe illness and death [8]. There are currently 30 recognized *Latrodectus* species [1], commonly known as black widow spiders (e.g., the North American *L. mactans* and *L. tredecimguttatus* in Europe), which are often recognized by their red abdominal ''hour-glass'' mark, as well as the Australian red-back spider (*L. hasselti*) and the cosmopolitan brown widow (*L. geometricus*). They are widespread throughout Africa, the Americas, Europe, Southeast Asia, and Australasia [8]. Phylogenic work has confirmed that there are two main groupings (*mactans* clade and *geometricus* clade) [45]. Members of the genus are notorious for the highly potent neurotoxin alpha-latrotoxin contained in their venom, which triggers a massive neurotransmitter release upon injection in vertebrates [46]. People may suffer eye injuries from contact with the bodily fluids of a widow spider, when the spider is crushed with a tool such as a

hammer [47]. Another possible source of envenomation is a toxin in *Latrodectus* eggs that has a different mammalian toxicity expression from that of venom; its effects on humans are unknown [48]. The insecticidal components of *Latrodectus* venom (latroinsectotoxins) have been investigated by the chemical industry for their potential use in pesticides [49]. Several *Latrodectus* species are synanthropic and often found in urban areas around houses, garden sheds, and barns [50], as well as in agricultural areas [38, 50]. They are generalist web predators which are known to feed on insects, crustaceans, other arachnids, and small vertebrates including lizards, geckos, and mice [51], and this broad diet may in part explain the presence of a vertebrate specific toxin in their venom. The threads of the black widow spider web are so strong that they were used as cross hairs on the gunsights of World War II American naval ships [52]. The treatment of widow spider bites varies in different regions of the world and is based on the availability of antivenom, its perceived effectiveness, and the degree of support given to other forms of treatment [8]. The limited evidence currently available of the efficacy and safety of alternative treatment, lends support to the use of antivenom in cases of latrodectism which cause severe or persistent pain or have systemic effects [8]. *Steatoda* spiders (Theridiidae) often bear a resemblance in body form and dark coloration to widow spiders and cause mild latrodectism effects. In one case, black widow antivenom was given for a *Steatoda* bite and appeared to relieve bite symptoms [53].

Human transport has undoubtedly widened the range of some species in the genus [45]. However, there continue to be poor estimates of the number of bites caused by *Latrodectus* worldwide [7,8]. In peridomestic situations, widow spiders are found in dark or dry places; bites are common when people put on shoes, bike helmets, or gardening gloves, and when spiders are clutched by fingers under outdoor furniture, in potted plants, or in dry storage areas [7,8]. In Mediterranean agricultural conditions, *L. tredecimguttatus* is found in wheat, with bites being an occupational hazard of farmworkers [44]. In natural environments, *Latrodectus* spiders live under stones, in small mammal burrows, under logs, in shrubs, and even in trees, depending on the species [54]. Some species are not found in synanthropic association [44]. In the past, many bites, predominantly on the buttocks and genitalia, occurred in outdoor toilets [55]. The decline in the use of outdoor privies and an increased public knowledge of the black widow has resulted in a decline in the number of bites by this species in the United States. Most bites are caused by female spiders. Bites generally occur during warmer months. In the case of *L. hasselti* [56], there was no significant difference between the effects of bites by juvenile and adult females. The adult male only caused mild, short-lived, pain. The subadult male caused severe pain for 12 hours, but with no systemic effects [56]. In a 10-year (1980−1990) retrospective analysis of latrodectism in Brazil, Lira da Silva et al. [57] reported that most widow bites occurred in cities, affected predominantly men, and were most commonly inflicted by *L. curacaviensis*. Certain members of the genus are increasingly being detected in new and widely separated localities. For example, it appears certain that several species have recently been introduced to Hawaii [58], Japan [59], Australia [60] and New Zealand, where they have been intercepted in consignments of imported goods arriving from different countries at post-border quarantine facilities [39]. While it is clear that *L. geometricus* has been recently introduced to many localities around the world [45], it is uncertain what proportion of its remaining distribution (including Africa, parts of North America, and South America) constitutes its native range, as it was first documented in both South America and Africa at the time of its scientific description in 1841 [45]. Many spiders (including theridiids) can disperse over long distances by ballooning, when they are juveniles, travelling long distances [2]. Thus it is plausible to hypothesize that in the course of their

evolution *Latrodectus* spiders have occasionally colonized distant landmasses within which subsequent lineage diversification has occurred [45].

Some interesting records of biological control of *Latrodectus* are found in old publications. *Latrodectus* spiders invaded Hawaii around 1935 and became a problem in the warmer drier sections of the islands [61]. An egg parasitoid, *Baeus latrodecti*, was discovered parasitizing black widows in a small area characterized by sand dunes in Southern California [62]. Parasitized eggs were shipped to Hawaii, where a rearing program was initiated and over 32,000 *B. latrodecti* were liberated during 1939-40 [61, 62]. Bianchi [63] stated that a search on the island of Hawaii failed to reveal the parasitoid, but it was later found to be established on Maui. *Eurytoma latrodecti* was introduced from Hawaii to Kwajalein in 1950 to control the black widow spider, and there were reports that it had become established [63]. Some Spechidae wasps such as *Chalybion californicum* are regarded as effective predators of *Latrodectus* spiders, especially immature spiders [64].

In the older literature of the United States [52, 54] the periodical eradication of the spiders and their egg masses by mechanical means was considered the most satisfactory method of control. "At night the spiders can be easily detected with the aid of a headlamp or flashlight, and destroyed by hand. Everyone should know this brilliantly marked spider by sight, and avoid contact with it" [52] (*L. mactans*). A reasonable degree of orderliness in the storage of equipment and disposal of rubbish would reduce the available sites for nests and webs. Outdoor privies were common sites for attacks by *Latrodectus*; most victims were men and the injury was centered on the external genitalia [55]. A periodic examination of the outdoor privies was recommended and it was suggested to paint the undersides of the seats with creosote, crude oil, or some other repellant. [52]. Recently Hernandez [39] evaluated several pesticides against *L. Hesperus* in table grape vineyards. Of the tested pesticides, methomyl, fenpropathrin, and chlorpyrifos provided 100% control of adult male and female black widows by direct exposure. Only chlorpyrifos and fenpropathrin provided control of adult females, within 10 days post-treatment, when the spiders were exposed to treated vine bark. Methomyl was the most toxic to adult females while fenpropathrin was the most toxic chemical to the immature stages. In 2008 [65], another work examined ultralow oxygen treatment (ULO) for control of *L. hesperus* on harvested table grapes and achieved complete control of the spiders with no negative effects on grape quality. Owing to the relatively short treatment time required, its effectiveness at low storage temperature and the easily attained oxygen level, the ULO treatment has the potential to be implemented commercially for the control of black widow spiders on harvested table grapes [65]. The Extension Manuals of the University of California (UCA) [66] and others recommend taking preventive measures of physical control to reduce the occurrence of black widow spiders; these include cleaning areas of rubble, scrap and lumber materials or old machinery that has been disused for a long period of time, destroying webs, egg sacs and spiders by brushing or vacuuming and caulking or sealing openings to prevent entry by both insects and spiders. The ability of spiderlings of *L. hesperus* to pass through different sized mesh screen and the implications for exclusion from air intake ducts and greenhouses has recently been evaluated [67]. The purpose was to determine whether immature individuals of these spiders could be excluded from buildings, and it was found that the mesh size sufficient for exclusion is too small for practical use in most cases, although there are special situations where this small mesh might be useful [67]. According to the UCA extension manual [66] the chemical control should use sorptive dusts containing amorphous silica gel (silica aerogel). Pyrethrins may be useful in certain indoor situations. According to the UAK extension manual [68] when

applied as a dustlike film and left in place, a sorptive dust provides permanent protection against spiders. The dust is most advantageously used in cracks and crevices and in attics, wall voids, and other enclosed or unused places. As was the case with other spiders and scorpions, most of the suggestions for control of widows are based on the recommendations on the labels of the products, with few bioassays being referred to in the literature. In 2005 [69] a bioassay using few spiders tested three management strategies against *L. Hesperus* with chemicals being directly applied to the substrate, spider webbing and spider; three classes of chemicals were tested phenyl pyrazole (fipronil); pyrethroid (cyfluthrin); and neonicotinoid (imidacloprid). Fipronil controlled 96% of the spiders after 8 days, cyfluthrin controlled 70% after 5 days and imidacloprid controlled 18% of the spiders after 14 days. A higher level of control was obtained with the application of fipronil and cyfluthrin to female *L. hesperus* and male *Tegenaria agrestis* than to female *T. agrestis* The application methods showed similar results.

If necessary to control synanthopic *Latrodectus* species, it is important to keep in mind that the widow spiders are less abundant in the indoor than the outdoor environment, they are not cursorial spiders and that they have distinctly visible webs. The removal of webs egg sacs and spiders by vacuuming at indoor environments can thus be the first line of defence. Chemical control should be used mostly indoors. In the outdoor areas, the residual effect will always be lower than that of the indoor environments.

Loxosceles - The Sicariidae family is composed of the *Sicarius* and *Loxosceles* genera [1]. The name *Loxosceles* means slanted legs due to the way the spider holds its legs at rest [70]. These spiders are colloquially known as recluse spiders, violin spiders, and fiddleback spiders in North America. In South America it is known in Brazil as “aranha-marrom”, in Chile as “araña de los rincones”. There are about 100 species concentrated in tropical and subtropical portions of the world, with a few species reaching temperate areas; the highest concentration of species is in the Western Hemisphere [1]. Many species have remote distributions, being known from less than 10 specimens in museum collections [71], so their medical importance is very low because they rarely interact with humans. In Brazil species of *Loxosceles* are frequent in karstic caves [72]. Brown spiders *L. adelaida* are found near and inside the caves in a State Park, in São Paulo, Brazil, which are visited by thousands of tourists every year [73]. The venom of this species is potentially able to cause envenomation with the same gravity of those produced by synanthropic species [74], but no bite was reported. The *Loxosceles* spiders are among the most enduring of the suborder Araneomorphae [75] and also have the lowest rate of water loss recorded on spiders [75]. One feature that facilitates the identification of spiders involved in possible loxoscelic accidents is that all *Loxosceles* species have six eyes, arranged in three dyads forming a curved line (Figure 1) [71]. They build webs covering the substrate in an irregular manner, described as having the appearance of frayed cotton [76, 77, 78]. It is common to find prey of many different taxa in their webs [76]. *Loxosceles* produces two types of silk threads: a cylindrical, typical of most spiders, and another in a "ribbon" shape, apparently unique to this genus [76, 77] (Figure 1). As it was noticed that the dry ribbons were highly electrostatic, it is suggested that the electrostatic interaction plays an important role in prey capture for *Loxosceles* [78]. Preferred habitats includes rock piles, wood piles, rat holes, attic and basement crawl spaces, indoor trash and clothing piles, cardboard boxes, and storage sheds. *Sicarius* and *Loxosceles* are the only known spiders with venom able to cause necrotic arachnidism in humans [79]. Some biotechnological applications of *Loxosceles* genus venom

toxins are being devised [80]. Although several toxins have been isolated from *Loxosceles* venom and various enzymatic activities have been identified, the medically important component appears to be sphingomyelinase D [79]. This dermonecrotic venom component has been identified in all species thus far tested, and it would not be surprising if all *Loxosceles* spiders are capable of causing necrotic skin lesions [74, 79]. Among the spiders that can cause serious health risks to humans, the brown spiders -particularly *L. reclusa*, *L. laeta* and *L.intermedia* - were the targets of the major control initiatives in the world.

The loxoscelism was first described in 1937 by the Chilean physician Atilio Macchiavello Varas [81, 82], who demonstrated that *L. laeta* bite caused the "arañismo cutáneo-gangrenoso y hemolitico do Chile". In 1957 it was described in North America [8]. Four categories of loxoscelism exist: (*a*) no effects, (*b*) minor injury with edema and erythema, healing without supportive care, (*c*) dermonecrotic injury with development of a hardened ulcer that sloughs off, leaving a scar, and (*d*) systemic effects with hemolysis sometimes leading to disseminated intravascular coagulation and, in rare cases, renal failure and death, reported to occur mostly in children [8]. Systemic loxoscelism is rare in the United States, with a 3% incidence rate and no deaths in a population of 111 patients with expert confirmed brown recluse *L. reclusa* bites in a 1997 survey [83]. In the State of Paraná, Brazil, where *L. intermedia* is the most abundant species, systemic loxoscelism is also rare [84]. Systemic loxoscelism seems to be much more common following *L. laeta* bites, with a case fatality rate of 3.7% in 216 bites [85]. Most bites occur when spiders are trapped against human skin and an object, such as a person rolling over in bed or getting dressed, in which spiders have crawled into clothing or shoes. *Loxosceles* females are more venomous and larger than males, which rarely inflict severe envenoming bites [86]. Like *Latrodectus* spiders, *Loxosceles* spiders are generally nonaggressive, reclusive, prefer to retreat when threatened, and bite only if handled or trapped in garments or bed linens. It continues to be difficult to define the true epidemiology of loxoscelism, because strict criteria for inclusion of definite bites are rarely used, and because many cases of local tissue injury are incorrectly attributed to loxoscelism [87]. Although *Loxosceles* spiders were not considered medically important until the midtwentieth century, in the following decades, their reputation spread so profusely throughout North America that brown recluse spider bites were diagnosed by medical professionals in regions of the continent proportionally greater than the number of *Loxosceles* spiders known from the area and, in some cases, where none have ever been found [87]. Medical toxicologists and arachnologists have assembled a still-growing list of many medical maladies mistaken for *Loxosceles* envenomation [8]. For most *Loxosceles* bites, RICE (rest, ice, compression, elevation) therapy is considered proper remedy because most events are minor; therefore, conservative treatment is advocated in most cases [8, 87]. For more dramatic ulcers or skin damage, regular and intense wound care is required; other more specific treatments are still controversial and unproven [8, 87]. In Brazil [88] and Chile [85], *Loxosceles*-specific antivenoms are produced and distributed by the government to be used on severe envenomations. New antiloxoscelic serum approaches are under investigation [89].

The brown recluse spider, *L. reclusa*, is the most common recluse spider in North America The species is synanthropic over much of its range in the United States, being primarily found in the South-Central states [90] and, as such, is commonly misconstrued as being ubiquitous throughout the country, particularly by medical professionals [8, 87]. Infestations of thousands of *L. reclusa* spiders in homes in Kansas were reported with no incidents of

bites to human occupants [91]. These reports suggest that even in cases of high densities of *L. reclusa* spiders, bites are unlikely, and therefore in nonendemic areas, envenomations by this species should be considered highly improbable [8, 87]. *L. reclusa* prefers dry, dark areas, and outside of human habitation, is often found under stones and within the bark of dead trees. The Mediterranean recluse, *L. rufescens*, has dispersed to many other countries, originating from the circum-Mediterranean region [71]. It has been collected in many localities in the United States. In nonendemic *Loxosceles* areas in North America, it is more likely to find a spot infestation of the non-native *L. rufescens* than the native *L. reclusa* [87]. The Mediterranean recluse has also become established in Australia [92]. Gertsch [71] states that there are no valid specimens of *L. rufescens* from South America. In Europe *L. rufescens* is the most abundant species [71]. In Portugal, any loxoscelic accident was proven until recently [93]; some reported cases could be due to mistaken diagnosis of serious infections by strains of *Streptococcus* or *Staphylococcus aureus* [93]. In France [94] and Greece [95] loxoscelism is also is very rare, with few probable cases. In Israel, a retrospective single-centre study included 52 patients with necrotic arachnidism hospitalized in the dermatology department between 1997 and 2004 [96]. Although *Loxosceles* was introduced to a small part of Australia [92], a prospective analysis of 750 definite spider bites in Australia over a 27-month period reported no evidence of necrotic araneism in the Australian experience [25, 97]. From South Africa, *L. parrami* was reported as medically important [98]. Accidents by *Loxosceles* represent around 4% of the total number produced by venomous animals in Argentina [99]. Despite the overreporting of accidents related to *Loxosceles* in certain localities such as the United States [87], hundreds or thousands of bites per year really occur every year in other regions of the World. This is the case for Chile and Southern Brazil. Chile, the country where loxoscelism was first confirmed, reported many bites by *L. laeta* [99, 100]. In a retrospective analysis of 1,348 suspected spider bites in Chile over a 40-year period, 16.6% of the dermonecrotic lesions were caused by *Loxosceles* spiders [100]. In Brazil, most accidents are recorded in the Paraná State, where loxoscelism is considered a serious public health problem. The species responsible for the majority of the reported accidents is *L. intermedia* [84, 102]. This species prefers indoor environments [103] and wanders extensively, increasing its chances of human contact, with accidents being more frequent in the hottest months of the year [84]. In Santa Catarina State, adjacent to Paraná, many bites have also being reported [104, 105]. A clinical and epidemiological study of 267 cases of envenomation by *L. laeta* and *L. intermedia*, reported that 4 patients (1.5%) died, all of whom were children under 14 years old [104].

Loxosceles spiders are considered a challenging target for control in urban areas, due to specific features of their biology [11, 87]. Their morphology is homogeneous, sometimes making the separation of species difficult [71]. Although few groups of this genus have been studied until now, the behavior seems to be more variable between species than previously supposed [106]. Species seem to differ especially in their foraging strategies; with either more investment in the construction of webs and consequently a sit-and-wait behavior, or lower investment in the construction of webs and a tendency to active hunting [106]. This difference between species in foraging behavior is directly linked to the likelihood of loxoscelic accidents [106]. However several features that are common to the species of *Loxosceles* are very important for their successful adaptation to domestic and peridomestic environments [87]. One factor is their exceptional longevity, considering body size. The average life spans for *L .reclusa* [107] males is 897 days and for females 794 days, with 25% of the females living over 1,000 days, one surviving 4.8 years. To *L. laeta* it was reported [108,

109] for females the average of 2.1 years to mature and another 4.8 years as adults. For *L. intermedia* [110] longevities of 1,176±478 days for females and 557±87 days for males were reported. Probably linked to the long life span, the female *Loxosceles* spiders are able to produce several egg sacs with a variable period of time between subsequent ones, instead of concentrating all the reproductive effort on a single egg sac, as other spiders with shorter life spans [2]. So, when egg cases and webs are removed but the females are not removed, new egg sacs can be readily produced, mostly if the female mated several times, as is common for this genus [87, 111]. *L. reclusa* average 50 eggs per egg sac and 2.7 egg sacs per female with a 48% hatch rate [112]. For laboratory-reared *L. intermedia* restricted to one mating, egg sacs contained approximately 30 eggs where 70% hatched, however, the egg sacs of field collected females of unknown mating history averaged around 50 eggs with 80% hatch [111]. Similar fecundity numbers are presented for other species: *L. laeta* – mean of 88.4 eggs per sac [113], *L. gaucho* – mean of 61.3 eggs per sac [114]. Laboratory reared spiders, if not exposed to high temperatures, can obtain all the water they need from prey, as we could observe during the several years we kept *L. intermedia, L. laeta* and *L. gaucho*. We were able to keep females of these species for one year in plastic containers, without food and water, and these spiders after fed with insects, lived up to two more years (unpublished data). Eskafi et al. [75] purposely starved field-collected *L. reclusa* at different temperatures and relative humidities. Spiders at 5ºC survived 4 to 7 months whereas this dropped to 1 to 2 months at 30°C and less than 2 weeks at 40°C. Starved mature *L. laeta* [108] took an average of 1.2 year to succumb. The dispersal capability of *Loxosceles* species is low, because they do not use ballooning in earlier stages as *Latrodectus* species [45]. So their dispersal to long distances depends on human activity. *Loxosceles* spiders can be found in very high density in synanthropic situations. A Kansas family collected 2,055 *L. reclusa* spiders in their home in 6 months [91] and a survey in Kansas showed that 22 of 25 homes had *L. reclusa* with an average of 83.5±114.9 spiders per home (range 1 to 526) [115]. In a Chilean survey, more urban (40.6%) than rural (24.4%) houses were infested, but a higher density of spiders was found in rural (11.9) than in urban (3.9) houses [116]. In Curitiba, Paraná State, Brazil, *L. intermedia* and/or *L. laeta* were found in 97% of the dwellings visited [117]. Brown spiders are not social spiders in the sense of sharing webs, prey capture and defense such as and other social or cooperative spiders [2] but there is intraspecific and interespecific species recognition [118] that either reduces aggressive interactions and/or allows escape to a safe distance to avoid predation such as exists for *L. gaucho* in female-female [119] and male-male interactions [120] and for *L. intermedia* in male-female interactions, when acoustic signals are also involved [118] As long as there is enough prey and microhabitats (crevices, etc.) available, cannibalism seems to be rare among spiderlings [121] and adults. The upper and lower limits for temperature tolerance have been reported for some species. For *L. reclusa* it was reported that the activity limits were of 4.5°C to 43°C; with 4-hour exposures, there was 47% mortality at 27°C and 21°C; with 30-days exposure all spiders survived at 0°C but none at 25°C [122]. With 1-hour exposures at constant temperatures, it is reported [123] an upper LT_{50} (median lethal temperature) of 35°C for *L. intermedia* and of 32°C for and *L. laeta*; the lower LT_{50} was 27°C for both species. A recent paper addressed *L. reclusa* distribution, employing ecological niche modeling to investigate the present and future distributional potential of this species, and demonstrated that under future climate change scenarios, the spider's distribution may expand northward, invading previously unaffected regions of the USA [90]. *Loxosceles* spiders make irregular predomimantly 2-D or 3-D webs, depending on the microhabitat available. *L. reclusa* in laboratory conditions preferred crevice widths of 9

mm or bigger with no correlation of body size to crevice width, whereas *L. laeta* preferred crevice sizes of 6.4 mm or bigger [121], with a marginally significant correlation between crevice width and body size. Both species preferred vertical instead of horizontal-oriented refugia and refugia with conspecific silk compared with previously uninhabited refugia. There was no significant difference between the species in their propensity to move among refugia in the 30-days trial; however, both species had individuals that were always found in the same refugium for the entire assay and individuals changing refugia every 2-3 days. The propensity to switch refugia was not affected by the degree of starvation for the period tested [121]. Another work [124] investigated why *L. laeta* and *L. recluse* preferred small cardboard refugia covered with conspecific silk compared with never-occupied refugia. When the two *Loxosceles* species were given choices between refugia previously occupied by their own and by the congeneric species, neither showed a species-specific preference; however, each chose refugia coated with conspecific silk rather than those previously inhabited by a distantly related cribellate spider, *Metaltella simoni.* Considering the inability to show attraction to chemical aspects of fresh silk, it seems that physical attributes may be more important for selection and that there might be repellency to silk of a recently vacated spider [124]. Some species, such as *L. laeta*, seem to invest more energy on web building, defends aggressively their webs from conspecifics and other spiders and are rarely seem much distant from the webs. We found evidence, from molts and very dense webs that it is common in undisturbed areas to find *L. laeta* females that spent their entire life in a single location. This sedentary behavior is certainly linked to the low number of accidents observed in houses with many *L. laeta* [116], although these spiders are probably the most aggressive synanthropic *Loxosceles.* In the other extreme we have *L. intermedia*, the species that probably causes more accidents with humans in the genus. These spiders do not invest much energy in webs, are frequently found at big distances from the webs, and may change locations frequently during lifetime (unpublished data). This vagant, active hunting behavior certainly increase the risks of accidents, and we have bites recorded in houses with few spiders [106, unpublished data]. One publication [125] states that *L. reclusa* is a scavenger, and exhibits a clear preference for dead prey over live prey. However, a more detailed study [126] suggests that scavenging is an opportunistic behavior in recluses that requires specific circumstances that may rarely occur in nature. In natural habitats, *Loxosceles* spiders can be found under rocks and the loose bark of dead trees; *L. intermedia* might be an exception, as it is almost impossible to find in these microhabitats, far form urban areas. In synanthropic environments, *Loxosceles* spiders are found in cardboard boxes especially under folded flaps, in cupboards, behind bookcases and dressers, in trash, under broken concrete and asphalt and, of medical concern, in shoes and clothes left out on the floor or stored in closets and garages. There is a propensity for *L. laeta* and *L. intermedia* to be found frequently in association with rough surfaces such as cardboard, construction material, wood and cloth and less so with smooth surfaces such as metal and ceramic [102]. This fact is probably linked to the absence of subungueal tufts on *Loxosceles* species and consequent need to use rough surfaces to climb.

As mentioned above, *Loxosceles* spiders have proven to be a challenge to pesticide professionals, pesticide manufacturers, and homeowners [127]. Although several attempts have been made to control and eradicate populations in homes, hospitals, warehouses and other human dwellings and workplaces, most eradication efforts failed and sometimes it is considered an unlikely, if not an impossible task [127,128]. However, in 1966 [129] a focus of *L. laeta* in a large museum building at Harvard University in a dense indoor infestation was

controlled by applications of lindane and chlordane (currently banned products). It was considered later [130] that *L. reclusa* infestations can be managed with physical control and a combination of residual applications plus aerosolisizing contact materials. In 1968 [131] *L. laeta* was found in Southern California, in a building in Sierra Madre, close to Los Angeles. The media coverage created a panic on the population. A thorough search by local and state health and vector control officials eventually turned up that several parts of L. A. County and virtually hundreds of buildings that were infested with *Loxosceles* spiders. Following the discovery, a thorough eradication program was enacted. The building where the first infestation was discovered, a restored adobe structure, was tented and fumigated. Several years later, it was observed [131] that most of the control programs were unsuccessful. Within about a week following applications, some places have been reinfested by additional spiders. It was suggested then that repeated applications over long periods of time would be necessary to obtain control [131]. Previous evaluations of insecticides on *L. reclusa* indicated that a mixture of DDT (2 mg/kg) and chlordane (2 mg/kg) was effective and that lindane is an adequate insecticide for infested areas, with a median lethal dose (LD_{50}) of 85 µg/g spider [132]. Using insecticide-impregnated filter paper, Levi and Spielmann [129] evaluated DDT (4 mg/kg), dieldrin (1.6 mg/kg), lindane (0.5 mg/kg), chlordane (4 mg/kg) and mixtures of these products on *L. laeta*, pointing out lindane and chlordane as the most efficient products. Hite et al. [112] analyzed 13 insecticides applied directly on the body of *L. reclusa,* also selecting lindane with the best performance. Technical grade lindane and diazinon (1 mg/kg diluted) were also evaluated [133] by using filter paper as the substrate in tests with *L. reclusa* allowing a residual effect for up to 1 week. Gladney and Dawkins [134] evaluated the insecticides resmethrin, dichlorvos, methoxychlor and ronnel (fenchlorphos) by direct application on the dorsal surface of *L. reclusa.* Only the first product allowed a low median lethal dose, expressed as micrograms of product per gram of spider. In addition to the methodological variability found among the works cited, there was an important recognition of the carcinogenic effects of some of these products, many of which are currently restricted, severely restricted or banned in many countries. Recently [11] we designed a bioassay involving hundreds of females of *L. intermedia*, followed by a field test of the best performing molecule. Qualitative filter paper sheets were individually impregnated with 2 mL of the given insecticide aqueous solutions at the desired concentrations and allowed to air dry for 24 h. A previous assay was carried out with 12 concentrations of each insecticide, using four repetitions of three spiders per concentration, plus the respective controls (spiders placed on filter paper with no insecticide added). Mortality was assessed at 2, 4, 12, and 24 h after the contact of the spiders with the products, and seven concentrations were finally established for each product as causing between 1 and 99% mortality. Bioassays to determine the median lethal concentrations (LC_{50}) were conducted in the same way, with mortality being assessed 24 h after introducing the spiders into the containers. In laboratory tests, the most active pesticides in descending order were microencapsulated (ME) lambdacyhalothrin (LC_{50}=0.023 mg/kg), nonmicroencapsulated lambdacyhalothrin (LC_{50}=0.047 mg/kg), deltamethrin (LC_{50}=0.26 mg/kg), and cypermethrin (LC_{50}=1.38 mg/kg). Cockroaches, *Phoetalia circumvagans*, killed with ME lambdacyalothrin, were offered to the spiders. *L. intermedia* fed on 63.3% of the dead cockroaches during the first 6 h of experiment; none of the spiders died during the subsequent 15 days. Microencapsulated lambdacyalothrin was chosen for application in two contiguous houses. The mean volume applied was 22.8 mg a. i./m^2. Dead spiders were

found during all the inspections up to 60 days after the initial application. In total, 297 dead spiders were collected; 65.7% in the attic shared by the two homes.

Based on field and laboratory observations, Sandidge [135, 136] proposed protocols for the control of *L. reclusa*, to be used by pest control campanies. It involved [136] preliminary search for spiders, locating favorite hiding places in the house, as one major problem with brown recluse management is finding where spiders reside and where they retreat when pest applications are performed. A second problem is how to access and treat many of these areas. Sticky insect monitoring traps should be placed during the preliminary search to detect spider travel routes, invasion points into the house and access areas into and out of different rooms. The home should be revisited after several days to examine the contents of all traps. The age structure of the captured spiders—older adults, juveniles, or spiderlings could be determined. Insects trapped should also be examined, as if prey can enter houses, spiders can also enter and leave freely and structural changes (mechanical exclusion) may be necessary to correct the problem. Later it should be devised an approach to control each specific population. The age, size, sex, and condition of spiders will be a guide in later pesticide application. Sandidge [135] states that males travel more frequently and are more aggressive than females. However *L. laeta, L.intermedia* and *L. gaucho* [106] males are not aggressive at all and generally the male bite is considered less dangerous than female bites [86, 87]. For *L. reclusa* [135], according to Sandidge, areas with a large number of males put the homeowner at a greater risk of spider bite. The areas for traversing spiders should be treated using sticky insect monitoring traps and low toxicity chemicals with high residuals and/or products that cause mechanical injury. Males are highly active throughout the summer and are more likely to contact and therefore be killed by aqueous applications, dusts, or crack and crevice products. Areas containing a large number of females are more likely to provide the optimal environmental conditions and low disturbance necessary for egg and spiderling development. It is suggested to treat these areas with aqueous sprays for a fast knockdown, and consider fumigation or fogging for heavy infestations [136]. Many chemicals may not kill the spider, but will disrupt the nervous system and other bodily functions, causing the spiders to be extremely agitated and aggressive. Eggs and egg sacs are resistant to pesticide treatments, so they must be located and removed. Juvenile spiders are found in large numbers throughout the house at certain times of the year [135]. In [136], the details of construction favourable to *L. reclusa* are analyzed, and the attics are considered the most common female breeding site. This is true also for *L. intermedia* [11] and other species of brown spiders. The use of pesticide dusts is recommended [135, 136], but for *L. intermedia* ME lambdacyalothrin was efficient in controlling spiders in attics [11]. In Chile, in recent years, a multinational company [137] promoted a house paint formulation with supposed repellent properties against *L. laeta*, in the commerce. However, in laboratory tests, the paint does not have a repellent action against the spider [137].

The integrated pest management (IPM) concept to reduce *Loxosceles* populations in homes may rely upon many strategies. *Hemidactylus mabouia* geckos [138] may be efficient predators of *L. intermedia* in domestic environments [138]. Interspecific predation of three cosmopolitan house spiders, *Achearanea tepidariorum* (Theridiidae), *Steatoda triangulosa* (Theridiidae), and *Pholcus phalangioides* (Pholcidae), and *L. reclusa* [139] were examined to evaluate transitive predatory relationships and to explore the potential use of cosmopolitan spiders as effective biological control agents. Fifty houses were visually inspected. Although statistical tests showed a decrease in *L. reclusa* population densities with increased population densities of two cosmopolitan species, alluding to a potential beneficial

interaction for biological control, observations of spider behavior, web positioning (niche partitioning), and predation showed little possibility of biological control capabilities [139]. The use of appropriate vacuum cleaners showed to be efficient on removing and killing *L. intermedia* at all developmental stages, and it should be valid for other species of *Loxosceles* also [140]. Measures aimed to educate the population about behaviors that may reduce the likeliness of accidents, of how to recognize brown-spider webs [76], and which microhabitats are preferred by the spider doubtlessly can contribute toward minimizing the problem. However, chemical control continues to be the main or unique tool used by pest control companies and is the object of great interest for the population.

The control program designed to combat *L. reclusa* in the United States [135, 136] is detailed and based on field experience. However this program is designed to pest control companies, and involves the indoor application of several pesticides. In our field experience in Brazil [11, 138, 140] mostly with *L .intermedia,* we suggest to homeowners the frequent use of vacuum cleaners [140], and the tolerance to the presence of geckos in their homes, as they are probably the only indoor predator possibly tolerated by people and capable of removing adult and immature *Loxosceles* individuals [138]. As the gecko in considered a sit-and-wait predator, vagant spiders are more likely to be captured. In laboratory conditions, one *H. mabouia* gecko ingested three *L. intermedia* female in 30 minutes, and six in one day. A study on the feeding habits of *H. mabouia* in natural habitats [141] revealed that spiders are the most important item in its diet. We also suggest the elimination of cracks, crevices and other refugia in houses, that would be occupied by spiders in several developmental stages. We evaluated the effect of this minimization of refugia in dwellings (paper in preparation), and it was found to be cause significant reduction on the absolute number of spiders found and also facilitating the location and removal of spiders with the vacuum cleaner or other method. The attic of houses is a place were more adult females are generally found [11], so it is essential to remove these females from the population in order to reduce the population growth and also migration of spiders from the attic to other places of houses, mostly in days with temperatures above 30°C temperatures [142]. Other physical control measures such as moving beds away from corners and walls, and careful storage of clothing and linens, particularly soiled clothing and linens avoiding will reduce the chance of indoor spider bites, especially when dressing, grooming, or sleeping. In addition, checking shoes, socks, gloves, hats, sheets, and towels and all clothing and linens before donning or using will also expose hiding spiders that might bite when squeezed in clothing, towels, or bed linens. Indoor spider bites may also be prevented by properly insulating homes, especially all windows and exterior doors, attics and basement crawl spaces. Also avoiding the storage of material in paper boxes, using plastic boxes or bags instead. Chemical control is recommended when high infestations are found, or if there is a significant phobic reaction toward brown spiders and/or if people with special health conditions such as diabetes are residents. Very old residents or small children can also be considered on the chemical control recommendation. We suggest, for *L. intermedia* [11], the use of ME lambdacyhalothrin only in attics, using label recommendations and by pest control operators, if people are allergic to pyrethroids or afraid of pesticide use. If this is not the case, indoor aplicaton of ME lambdacyhalothrin can be performed also inside the house. Residents should leave the house for at least 12 hours, but we recommend 24 hours, in order to reduce the risk of loxoscelic accidents by affected spiders. We suggest the application of the pesticide during colder months, to reduce risk of accidents post treatment.

3.2 Scorpions – basic epidemiologic data and main control efforts

With the exception of snakes and bees, scorpions are responsible for more human deaths every year than any other nonparasitic group of animals [13]. Scorpion stings (scorpionism) are the most important cause of arachnid envenomation and are responsible for significant morbidity and pediatric mortality in many parts of the world. This is because either the incidence or severity of envenomations is high (or both factors at the same time), and are difficult for the health services to cope with [18]. The treatment of scorpion envenomation is complex and controversial, in particular regarding the effectiveness of antivenoms and associated symptomatic treatments [18]. In general, the degree of seriousness of scorpion stings depends on factors such as the size of the scorpion, the amount of venom injected, the body mass of the victim and the sensitivity of the patient to venom [18]. Most of these symptoms and clinical signs are caused by the release of adrenaline, noradrenaline and acetylcholine arising from the presence of the toxic venom in particular sites on sodium channels [18]. Other factors such as the interval of time between the bite and the administration of intravenous infusions and the maintenance of vital functions, can affect the initial progression of the illness and the early diagnosis. According to the most recent studies, seven areas in the World can be identified as being at risk: north-Saharan Africa, Sahelian Africa, South Africa, Near and Middle-East, South India, Mexico and South Latin America, east of the Andes [18] (Figure 3). This means that 2.3 billion people are at risk. The estimated annual number of scorpion stings worldwide exceeds 1.2 million and lead to more than 3,250 deaths (0.27%) [18]. The epidemiology of scorpionism in the world is poorly understood, because, among other reasons, many cases are not brought to medical attention. Effective treatment for these conditions is critically dependent on therapeutic sera, which is often unavailable or unaffordable in some of the countries where it is most needed. In 2007, the WHO created a five-year plan to boost antivenom production in developing countries, help authorities forecast market needs and strengthen their regulatory capacity [143]. Over

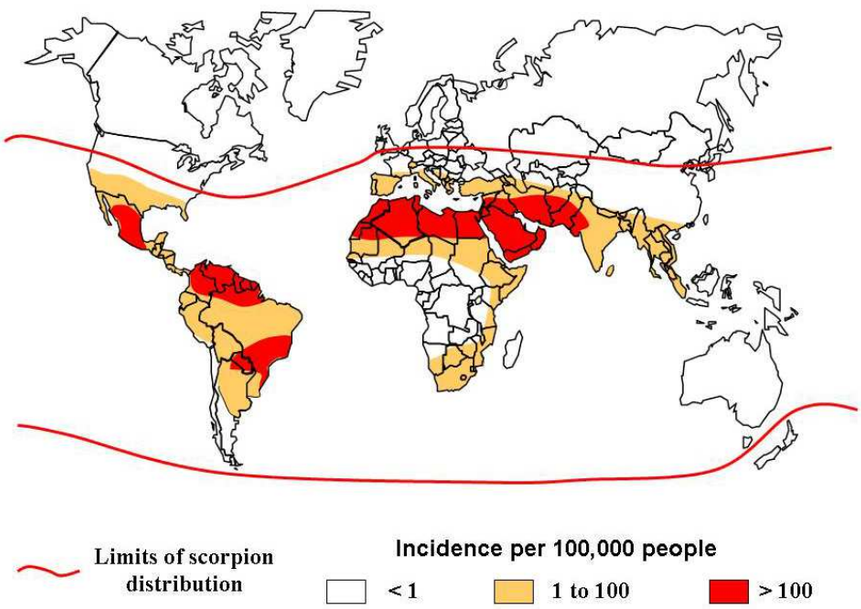


Fig. 3. Scorpionism areas of the world. Reproduced with permission from Chippaux and Goyffon [18].

10 million vials of antivenom sera are needed to treat snake and scorpion bites worldwide, with an estimated 2 million vials required for Africa alone [143]. In Mexico ca. 250,000 scorpion stings were reported yearly, but fatalities have declined from 2,000 to less than 50 per year following widespread distribution of antivenoms [143]. However, there is no mention in the WHO directive regarding the stimulus to the bioassays of existing pesticides or the development of new strategies and molecules for scorpion control [143].

Mexico referred to above, is the country with the highest incidence of scorpion stings. We list examples of the scale of the problem of scorpionism in other countries. *Hottentota tamulus* ("red scorpion") is the principal species of scorpion responsible for serious envenomation in India [144]. There is a lack of epidemiologic data concerning its incidence and mortality rate in India, although fatalities are regularly mentioned [144]. In Tunisia up to 40,000 stings, 1,000 hospital admissions and 100 deaths were former reported annually [145]. In Khuzestan, south-west Iran, where scorpion stings are the fourth main cause of death, 12% of the 25,000 stings treated each year and more than 95% of the fatalities are attributable to *Hemiscorpius lepturus* [146]. In Morocco, scorpion attacks are the primary source of envenomation and represent between 30 and 50% of all cases reported to the Moroccan Poison Control Center. *Androctonus* and *Buthus* are the genera most frequently responsible for these stings in the country [147]. In Saudi Arabia a total of 72,168 cases of scorpion stings were recorded between 1993 and 1997 [148]; *Leiurus quinquestriatus*, *Androctonus crassicauda*, and *Apistobuthus pterygocercus* were responsible for most of the stings. The study also shows that there was a low threat to life despite the high number of stings; this is due to the availability of medical facilities and the use of multi-center antivenom in different parts of Saudi Arabia [148]. In turkey, Scorpion envenomation cases are a considerable public health problem in all regions of the country, and important health-threatening scorpions in Turkey are *A. crassicauda*, *L. quinquestriatus*, *Mesobuthus gibbosus* and *M. eupeus* [149]. In Algeria [150], scorpion envenomation is a real public health problem; in 2000, 47,521 people were stung by scorpions and 108 deaths were recorded. Since the setting up of the National Committee to combat Scorpion Envenomations, several steps have been taken to deal with this problem [150]. In Brazil, 37,000 scorpion stings and 50 deaths were reported in 2005 and scorpion stings by *Tityus* spp. are an increasing health problem, due to the invasion of the urban environment by some scorpion species [151]. In Argentina, most injuries are caused by *Tityus trivittatus* [152]. Scorpionism in Argentina is a public health problem that is under control due to its relatively low incidence and the accessibility of specific antivenoms. In Venezuela, envenomation by *Tityus* scorpions is a common public health hazard [153]. In Colombia, scorpionism by *T. asthenes* is prevalent [154]. In the South of Europe (Portugal, Spain, Mediterranean France, Italy, and Greece), only small sized scorpions are found, the venoms of which are not usually dangerous to humans (*Euscorpius* sp., *Buthus occitanus*, *Mesobuthus* sp.). However, epidemiological data are limited and scarce [18]. In the South of France, the annual incidence is about five scorpion stings per 100,000 inhabitants, and the symptoms are mild. In Spain, less than 1% of the scorpion stings can be regarded as severe and no deaths have been recorded [18]. Scorpionism is low in Australia too; the stings from Australian buthid scorpions have more severe effects than those from the larger species in the Urodacidae (genus *Urodacus*) and Liochelidae (genus *Liocheles*) families [155]. In the United States, deaths from scorpionism are extremely rare [17, 18].

Scorpions represent a huge challenge in pest control because there is practically zero tolerance of their presence among residents of dwellings, even when species that do not

pose a significant risk to people's health are involved – the sting is almost always very painful, as well as being psychologically traumatic. In addition, as well as occupying intra and peri-domiciliary areas, several species of scorpions can also make use of the rainwater and drainage systems of the cities. In these sites they usually find abundant food supplies of insects such as cockroaches, and large colonies can become established and infest or reinfest many parts of the city. Scorpions can also detect contact pesticides through their pectens. Areas with inadequate sanitation are particularly susceptible to infestation by scorpions. The literature mentions that before the 1980s, organochlorine pesticides were used as a strategy of control, such as, for example, chlordane (2%) [17], which at present is only permitted for termites and is illegal in the United States if used by anyone other than a licensed pest control operator. Currently, only pyrethroids (principally) and in certain cases, organophosphates and carbamates will be among the molecules recommended to be effectively employed in public health control programs involving the application of products in the household, as will be seen in what follows. One of the main problems of scorpionism is how to achieve scorpion control through an effective participation of local communities. Although the use of chemical insecticides is one of the main measures adopted for controlling scorpions, few studies have focused on the efficacy and viability of this approach. The main measures taken for the control of scorpions naturally occur in the localities where they are regarded as a serious hazard to public health. In this Chapter, our aim is to consider studies and measures for controlling scorpion species that proved to be capable of rapidly forming large colonies in urban areas and spreading over great distances in the anthropic environment and about which references on bioassays and field application of pesticides are available. We will focus on Mexico and Brazil, countries which have serious problems with scorpionism in several areas but which adopt different approaches regarding the control strategies recommended.

Mexico - This country has had the largest number of deaths from scorpionism recorded in the world. The highest annual mortality rate (up to 1,944 deaths) was reported in 1944 [156]. Between 1979 and 2003, 6,077 deaths from scorpion stings were recorded [157, 158]. In 2005, 247,796 cases of scorpion poisoning were recorded, a figure that rose to 269,149 in 2006. *Centruroides* (Buthidae) is envolved in the majority of the recorded accidents. The most dangerous species are *C. noxius, C. limpidus limpidus, C. suffusus suffusus, C. infamatus, C. pallidiceps* and *C. elegans* [157]. In some states of West Central Mexico, such as Colima, a small State of the Pacific coast, the annual incidence reaches 1,350 scorpion stings per 100,000 inhabitants [158], and this figure rises to as much as 2,050 stings per 100,000 in some communities of Morelos, in the South-West of Mexico City. This figure is probably an underestimate, especially as the effectiveness of the treatment has dramatically decreased the mortality rate. All the authors are in agreement that adults are stung more often than children and that most scorpion stings occur during the night at home. The annual mortality rate following scorpion stings was approximately 0.6 deaths per 100,000 inhabitants in the 1970s, and it dropped dramatically to 0.07 in the beginning of the 21st century [157] thanks to a wider use of antivenom. The mortality rate remains rather high among children, in particular those younger than 5 years old [157]. The seasonal peak of stings lasts from March to June, i.e. at the end of the dry season, when the climate is hot [158, 159]. Climate is an essential predictor: in Colima State, there is very little rain and there are few stings in the winter when the minimum temperature is below about 16 °C. The number of scorpion stings is independent of the actual rainfall when this is above 30 mm/month [159]. The demographic factor is also significant. In Guanajuato state, 92% of the stings take place in an

urban environment. However, in communities with less than 2,500 inhabitants, the risk is nearly 12 times higher than in cities with more than 20,000 inhabitants [157].

At the beginning of the 20th Century, the Mexican authorities decided to offer prizes for the capture of scorpions and in just one summer, between 80,000 and 100,000 *Centruroides* scorpions were collected [160]. In 1962, a pest control scheme was put into effect in several parts of Mexico, which involved, among other non-chemical control recommendations, placing ceramic tiles and metal sheets around the foundations of houses [161, 162]. The premises were treated, indoors and peridomestically, with organochlorine lindane, but the results were unsatisfactory [156]. The North American Free Trade Agreement (NAFTA) in 1994 issued directives for phasing out organochlorines, and the use of Lindane was also banned in Mexico after 1999 [162]. New guidelines from the Secretariat of Health gave priority to alternative pesticides: carbamates and pyrethroids [163]. However, there was a fear that, as pyretrhroids tend to irritate and stimulate the motor activity of certain arthropods, its use would cause more stings. Field trials of pyrethroid pesticides were undertaken in Morelos during 1998-2000 at the village of Chalcatzingo (population initially 2,760 inhabitants, 530 dwellings) [162]. This study was taken into account by the Mexican Health Secretariat, when it officially recommended the use of pyrethroids in scorpion control [162, 163]. Pre-intervention surveys detected scorpions (Scorpiones: Buthidae) of two species in the majority of the houses: *C. limpidus limpidus* outnumbering *Vaejovis mexicanus smithi*. The prevalence of scorpions was assessed, both before and after the spraying, through direct searches (40 min/house) and by householder reports of sightings inside the houses. Pyrethroids and residual treatments were evaluated in different sectors of Chalcatzingo, with almost complete coverage indoors and peridomestically, using the following four formulations: bifenthrin 10% wettable powder (WP) applied at 50 mg a.i./ m^2, cyfluthrin 10% WP (Solfac 10 WP) at 44-55 mg a.i./m^2, deltamethrin 2.5% suspension concentrate (Biothrin 25 SC) at 11 mg a.i./ m^2 and 5% WP (K-Othrine 50 WP) at 35 mg a.i./ m^2. Phase 1 compared bifenthrin 10 WP, Solfac 10 WP and Biothrin 25 SC sprayed in December 1998; phase 2 compared Solfac 10 WP and K-Othrine 50 WP sprayed in June and again in December 2000, with follow-up surveys of scorpions one month post-spray and subsequently. The prevalence of scorpions was reduced by 64-77% peridomestically one month post-spray and by 83, 46 and 15% in houses sprayed with cyfluthrin WP, bifenthrin WP or deltamethrin SC, respectively. Householder reports of sighting scorpions indoors were 33-85% below pre-intervention levels. The cumulative effects of the three spray-rounds over 3 years reduced scorpion prevalence by approximately 60% in the deltamethrin WP re-sprayed area and approximately 90% in the cyfluthrin WP re-sprayed area. The number of householder sightings also fell by 67 and 28% in the cyfluthrin and deltamethrin re-sprayed areas, respectively. The operational efficacy of these products against scorpions at the dosages applied was ranked in the following order: cyfluthrin WP > bifenthrin WP > deltamethrin SC > WP. The reported cases of scorpion sting intoxication fell by 17% during this study after having risen by approximately 40% in the previous four years. When scorpions were exposed to lethal doses of the four pyrethroid formulations, none of them registered an increase in tail wagging, movement or activity, during the field observations. Thus, this study found no contra-indications for the use of these pyrethroids for scorpion control, apart from transient side-effects such as sneezing and itching if the sprayers were inadvertently exposed. According to the study authors, failure to completely eliminate scorpions from houses and the peridomicile can be attributed to the difficulty of treating all their hiding-places, rather than to the ineffectiveness of the pyrethroid [162]

A publication [164] by the National Institute of Public Health of the Mexican Secretary of Health which is designed for medical personnel and other interested parties, recommends a number of control methods and preventative measures, based on the governmental official norms for scorpion control [163] which are outlined as follows:

- The avoidance of children´s games or manual handling that risk exposure to scorpions (lifting up stones, bricks and bulky objects, exploring bushes or sliding one's hands along walls, walking barefoot or leaving clothes on the ground).
- Examining and shaking out one's clothes and shoes before putting them on.
- Checking the angles of walls, doors and windows. The leveling and patching of roofs, walls and floors is recommended.
- Putting some form of protection on the doors and windows and underneath the roofs, using materials such as tiles for the interior and exterior skirting-boards, polished cement, and galvanized sheet metal in the surrounding area of the dwelling.
- Using canopies for the cots and beds of children and immersing the bed legs in containers filled with water. The bed must be placed 10 cm away from the wall and care should be taken to make sure that clothes are not in contact with the floor.
- Disposal of any garbage, stones or wood in the surrounding area of the dwelling.
- The use of intra- and extra-domiciliary insecticides. Pyrethroids: lamda-cyhalothrin and cyfluthrin. Carbomates: propoxur. In the Mexican Official Norm (MON) regarding scorpions [164] the pesticide use is detailed (itens 7.4.1.1 and 7.4.4.2). Preference is given to pyrethroids lambdacyhalothrin (0.03 g/m^2) and Cyfluthrin (0.04 to 0.08 g/m^2), with estimated residual effects lasting about 6 months. The second recommendation is for carbamates like bendiocarb (20 mg/m^2) and propoxur (30 mg/m^2), with residual effects lasting six months. The recommendations are for intradomestic and peridomiciliar applications.
- The NOM [164] also recommends whitewashing fences, walls and trees near the house. The lime paint, with or without some local plants added during preparation, has a repellent action on *Centruroides* and possibly other scorpions.

Brazil - Scorpionism constitutes a public health hazard in many parts of Brazil [151, 165, 166, 167, 168], particularly in urban areas. The effects of human activity and environmental changes have allowed the expansion of some species that invade human dwellings and displace less dangerous autochthonous species [168]. In 1988, when a report was being prepared on the number of scorpion attacks in the country, it was found that there had been a significant increase in the number of cases. Most of these were benign with only a 0.58% fatality rate. The deaths were linked to stings caused by *T. serrulatus*, and most often occurred among children less than 14 years old [151]. From a public health perspective, the increase of the dispersion of *T. serrulatus* through the country was a cause for concern. This species, which originated in the state of Minas Gerais, is showing a progressive dispersion, and its presence has now been recorded in the Brazilian southeast, south and middle-west regions [151]. It has a bright yellow color from which it derives its name – "yellow scorpion". It measures up to 7 cm in length. Its colonies are only formed by females whose reproduction occurs through parthenogenesis [169]. In some studies, *T. serrulatus* is regarded as being a component of a complex that includes *T. stigmurus* [168]. Although traditionally inhabiting the savanna regions and open plains, this species has become well adapted to the life of urban households. In urban areas this species and others of scorpions and synanthropic animals have access to shelters containing garbage, debris, piles of bricks, and an abundance of food such as cockroaches and other insects. The lack of competitors

and predators such as monkeys, coatis, seriemas, toads and frogs, also allows the scorpions to proliferate rapidly [168]. The preferred temperature of the yellow scorpion *T. serrulatus* was investigated [170] and it was concluded that this species does not have a specific preferred temperature within the range of 14°C - 38°C and may even tolerate temperatures below 8°C, when in a torpid state. This fact suggests that the species is highly adaptable to different thermal zones. Stutz (personal communication) notes that most of the *T. serrulatus* in the town of Uberlândia, Minas Gerais are established in the drainage system and thus are able to enter the residential dwellings, which makes it difficult to control the species by chemical means.

More than 130 species of scorpions are known to exist in Brazil. Although most accidents are caused by the *T. serrulatus*, *T. bahiensi*s and *T. stigmurus* species are also of great public health concern [168]. The brown scorpion *T. bahiensis* has less toxic venom than *T. serrulatus* and is responsible for most of the attacks recorded in São Paulo [165]. In the north-east of the country, *T. stigmurus* causes most of the stings, some of which are very serious [167]. Other species of this genus are the cause of attacks of varying degrees of seriousness in several parts of Brazil and South America [18] and it is probable that all the species of this genus have a venom that can affect people [18, 171]. Apart from this genus, sporadic attacks have been recorded in Brazil with some species from the genera *Bothriurus*, *Rhopalurus* and *Brotheus* but none of them were serious (168, 171].

At the beginning of the 20th Century scorpionism by *T. serrulatus* and *T. bahiensis* in the the State of Minas Gerais was established as a serious public health issue. The Ezequiel Dias State Institute began to produce serum, and also offered financial rewards for the capture of scorpions so that the venom could be extracted to produce anti-scorpion serum; this inducement led to the capture of 107,533 specimens in 6 years [160]. Dias, in 1924 [160] already foresaw the need: a) to test molecules for chemical control b) to construct buildings that were unsuitable for the life and procreation of scorpions c) to take supplementary measures. Unfortunately, not many of his recommendations were put into effect by the authorities in the years that followed. Preliminary experiments were carried out in the laboratory by the same author with *T. bahiensis* which were exposed to many substances, including xylol, chloroform, hydrocyanic acid, gasoline, naphthalin, coal gases, carbon sulfurate and sulfurous gas. The following gases were also tested in an experimental room: acetylene gas, creolin, naphthalin, tar, coal and chlorine. All these substances were lethal to the scorpions in the laboratory but showed negative effects in larger spaces. In the later stage of the field study, the laboratory assistants used sulfurous gas (obtained by burning sulfur) for fumigating the buildings and dwellings in the ratio of 20 g/m^3. In many cases this led to positive results. The use of xylol in furniture to control scorpions was also tested. Dias stated that, however effective the chemical control method might be, this should only be adopted in an emergency, since given the same conditions, reinfestation will occur. Some time after this pioneering work, the use of sulfurous gas and xylol was forbidden because as well as being extremely difficult to employ, it posed great risks to health and the natural environment. Dias [160] drew up a list of 18 construction features to reduce the risk of infestation by scorpions, which should be required by the sanitary authorities, together with those responsible for giving approval for new buildings. He paid special attention to the need to forbid woodsheds to be built in areas (closed or otherwise) near to dwellings. In the case of backyards, he advised keeping hens to control the scorpions because they are able to ingest a lot of *T. serrulatus* very quickly. In rich districts, he advised the purchase of

scorpions as a strategy for reducing their numbers [169]. According to Magalhães [172] Brazil, in the State of Minas Gerais, carried out the first systematic campaign against scorpions in the world. This author describes tests that were conducted with the organochlorine DDT in various formulas, with bioassays that involved *T. bahiensis* and *T. serrulatus*, and records the repellent activity of the powder derived from this product against the scorpions. According to Bücherl [173, 174], contact insecticides (organochlorates at that time) only have satisfactory results when sprinkled in all areas at the same time and if the supposedly infected area is treated at least three times per month, for three uninterrupted months. Later, a ban on the further use of organochlorates was imposed in Brazil which is a signatory to the Stockholm convention and other agreements concerning Persistent Organic Pollutants (POPs). Pyrethroids and organophosphates were used to combat these arachnids, particularly in situations where alternative control measures like the elimination of breeding sites, woodpiles, rocks and debris from areas around homes, have been difficult to apply or been shown to be unsuitable [175].

The "Manual de Diretrizes para Atividades de Controle de Escorpiões", published by the São Paulo Secretariat of Health in 1994 [176], provides guidelines to be used on scorpion control programs. The manual listed ME pesticides as a possible adjuvant means of controlling infestation by scorpions [176]. On the basis of empirical studies and observations, some investigators stated that *Tityus* scorpions can make use of their pectens to detect non-microencapsulated formulas applied to the substrate such as organochlorates, pyrethroids, organophosphates and carbamates [177, 178, 179, 180]. After being exposed to these, the scorpions might show an increased activity and thus intensify the risk of attacks involving human beings. One of the studies on the effectiveness of three insecticides (bendiocarb, deltamethrin, and lambdacyalothrin ME) [177] for controlling *T. serrulatus,* stated based on preliminary laboratory bioassays, that exposing the specimens to the insecticides tested, did not significantly affect their survival. The scorpions were exposed for 15 minutes, after they had been put in the containers without the product. The exposures were carried out in distinct groups on days 1, 15 and 30 after the treatment. The pesticides were spread on the tile surfaces in accordance with the amount recommended by the manufacturer. No knockdown effect was reported in the 15 minutes of exposure and the bendiocarb caused the least irritation, followed by the lambdacyalothrin ME and the deltamethrin. The effect of irritation was only observed during the period of exposure to the surface that had been treated by the pyrethroids and disappeared when the specimens were taken to the other substrates. The authors concluded that the amounts recommended by the manufacturers for the pyrethroids tested did not show results that were favorable to the control of scorpion colonies. One of the preliminary laboratory assessments used glass bowls treated with 5 mL of prepared solution with Diazinon ME (0.3%) with exposure to *T. serrulatus* for one hour [181]. In these conditions, after exposure the animals died in periods no longer than 24 h and the treated substrate was shown to be capable of bringing about mortality up to 62 days after its application. One test which could only be partly completed was conducted in the town of Aparecida, São Paulo state, where there is a predominance of *T. serrulatus* [178] and at that time experienced about 45 attacks/100,000 inhabitants per year. Spraying of diazinon ME (30%) (6g/m²) was undertaken, in 360 household units in the peridomicile and domicile areas, as well as in a cemetery where it was sprayed together with 1% dichlorvos. The cemetery application with dichlorvos had a significant repellent effect, and its use its use was interrupted due to the intense migration of the scorpions to

neighboring areas, alarming the population. The live individuals present in areas treated only with diazinon ME, were collected and kept on laboratory in containers without pesticides. The average time that it took for the specimens sent to the laboratory to die was 37 days; in this same period, no fatalities were observed in the control group. In the same town, a project for the control of scorpions was planned in 1995 [182]. Studies were carried out of the main sites where scorpions could be found in the fields or town, as well as of the environmental conditions of the urban habitat that could facilitate the procreation and dispersion of scorpions. The basic problems of urban infra-structure were assessed, such as the means of packing and collecting public and domestic urban garbage, basic sanitation (drainage systems and pluvial water galleries) and the situation regarding the wastelands and building construction in the urban areas. After the epidemiological study, a number of educational measures were taken which comprised the preparation and distribution of leaflets, collective cleaning activities, domiciliary visits and the involvement of teachers and students in the public and private teaching network that formed a part of the campaign. In focal points of high risk, in particular in the kindergartens, the use of chemical control was suggested which involved deltamethrin-based pyrethroids. Within the sanitary norms that prevailed in the urban zone, a further suggestion was the use of natural predators like domestic hens to combat scorpionism. A further idea was to introduce a scheme where one week each year would be devoted to the study of scorpionism within the schools of the town where the problem prevails; this would be an educational measure that could help prevent attacks and improve scorpion control.

In the state of Pernambuco, the records on scorpionism by *T. stigmurus* constitute one of the highest incidences of scorpionism in the country, with 43.5 cases/100,000 habitants [183]. In natural environments, this species is found under stones, in cracks and in decomposing trees, especially in environments where the ground is very damp [183]. However, in urban areas, *T. stigmurus* has been found invading human dwellings, and living in roofs or among debris in backyards. An investigation in Recife, capital of the State of Pernambuco, analyzed the events that followed the application of the insecticide Demand 2.5 CS (lambdacyalothrin ME) in the field, to control *T. stigmurus* [183]. During three months, 69 premises were monitored on different days after being treated with insecticide, to determine the degree of scorpion detection frequency and mortality. Spraying was preferentially performed outdoors around the foundations of the buildings and potential breeding sites such as debris and sewers. Indoor application was only carried out in premises where there had been constant sightings of these animals inside the house. The treated premises were monitored for one month following the application of the insecticide. During this period, the premises were visited on the following days: 1, 7, 15 and 30 days after the treatment. The results showed that 42% of the premises had the presence of scorpions, with an average of three specimens per house. The highest incidence was recorded during the first week following the treatment. Only 7% of the specimens were found dead. Most (72%) of the inhabitants of the premises showed a knowledge of prevention and control measures. Despite this, 100% of the premises revealed breeding sites, mainly (79.7%) waste material (rubble, debris, newspapers, plastic receptacles and sticks. However, most (56.5%) of the people showed little interest in adopting preventative measures. These results provide evidence that the scorpion control method used by the health agents during this investigation was inefficient, and suggest that the method may have had a dispersive effect on these animals, as also suggested by other study in Belo Horizonte, Minas Gerais state, Brazil [180]. The treatment

with Demand 2.5 CS took place between May and June, coinciding with the period of highest rainfall in this region [183]. This may have intensified the dispersion of the scorpions away from their hiding places due to habitat overflow. Moreover, the rain may also have reduced the effect of the insecticide, by washing it away, since it was mainly applied in the areas surrounding the homes. The results shown in this study [183] may have been influenced by the way the infected area was treated, which involved a single application, compared to three applications in another study carried out in Mexico [162].

Measures taken to control scorpions excluding use of pesticides included in the program were first implemented in Bandeirantes, a town of about 32,000 inhabitants in the State of Paraná [151, 185]. The activities which were set in motion by the State Secretary of Health, in partnership with the municipal authorities, have succeeded in achieving concrete results without the use of pesticides. The project consisted of analyzing the situation in the town, determining the spatial distribution of the scorpions, planning measures for intervention and training a municipal team to undertake the work. In two years (2006-2008), the program led to the capture of thousands of scorpions in the town. The municipal work consists of going directly to the key sites where the scorpions are located, removing them and making the residents of the dwellings aware of how to avoid a new infestation. This methodology is recommended in the publication "Manual de Controle de Escorpiões" (Scorpion Control Manual), published by the Brazilian Secretariat of Health in 2009 [151]. Some other cities [186] halted the use of pesticides on scorpion control, following the new Brazilian official guidelines [151], although it is still in use in many cities. The Scorpion Control Manual [151] lists as reasons which make chemical treatment ineffective to control of *Tityus* scorpions the habit of these animals to shelter in the cracks of walls, underneath cardboard boxes, and in piles of bricks, tiles, pieces of wood, and fissures or crevices in the ground, together with their ability to remain for months without moving. As well as this, they have the supposed ability to remain with their pulmonary stigmata closed for a long period. The products whose use is not recommended, by the Manual are chemical domestic sanitation items consisting of formaldehyde, cresols and para-chlorobenzenes and products used as insecticides, raticides, cockroach-killers or repellents of the pyrethroid and organophosphate groups. This is because, according to the Manual, the displacement and consequent dispersion of the scorpions from the places previously not exposed to the effects of these products increases the risk of attacks. As well as this, it could create a false feeling of being protected on the part of the residents, who will be led to believe that the problem has been overcome and prevent them from coming to terms with their environment. The Scorpion Control Manual state that, up till now, the effectiveness of the chemical products for scorpion control in the natural environment has not been defined scientifically [151]. When there is a need to control cockroaches in places where scorpions are present, the use of formulas with gel or powder is recommended.

In the pest control manuals produced after the banning of the organochlorine pesticides, which were made available to American universities, it is suggested that scorpions are difficult to control by just relying on pesticides [187]. Thus, the first control strategy is to make alterations to the area surrounding a house or structure. [187, 188]. As regards pesticides [188], it is suggested that wettable powder formulations provide a better residual control of crawling pests when applying perimeter sprays. When using pyrethroids or other insecticides designed for scorpion control, the highest permissible label rate should be used. Scorpion control pesticides registered in October 2000 in the United States include the following: permethrin,

cyfluthrin, cypermethrin, lambda-cyhalothrin ME, deltamethrin. Daytime spraying is largely ineffective. The most effective scorpion management method would be nightime blacklight collecting. [187]. Daar [189] suggests that spraying the perimeters of buildings is both unnecessary and ineffective since scorpions are able to tolerate a great deal of pesticide in their environment. Moreover, the use of physical controls along with education to reduce the fear of scorpions will help prevent the application of unnecessary chemical treatments.

4. The methodological problem of the bioassays and recommendations for control

The development of specific molecules to control spiders and scorpions has been neglected, probably due to the limited demand for control measures. As a result, pesticides such as pyrethroids, carbamates and organophosphates have been adapted and used for arachnids in label amounts generally above those recommended for insects, thus causing potential environmental liabilities with regard to their use. In Mexico, a field study cited above [162] in a small community tested the use of pyrethroids for the control of scorpions with monitoring over a period of three consecutive years, presenting positive results and no significant repellent effects of the pytrethroid molecules tested. The mexican official norm NOM-033-SSA2-2002, for the surveillance, prevention and control of scorpionism [163], published in 2003 and focused on the control of *Centruroides,* included pyrethroids and carbamates among the products listed for used as part of scorpion control programs. In Brazil, the most recent official document on scorpion control [151] recommends the avoidance of chemical control with scorpions of the genus *Tityus* and supposes that the same molecules used in Mexico to control *Centruroides* spp. scorpions are not effective against *Tityus* spp. There exists on *Tityus* information of a small-scale field test where there was a single use of pyrethroids ME without good results [179] but there are also accounts of the effective use of carbamates in field scorpion populations [178]. Certainly, there are differences in the susceptibility, the habitats, the behavior and other aspects of *Tityus* and *Centruroides* scorpions. However we have not found any mention to published laboratory bioassays, based on methodology that follows the guidelines of WHO or others widely accepted by the scientific community, aiming at scorpions found in Mexico, Brazil or other countries. Even the manuals issued by the American University Extension Services [187,188] adopt the recommendations that can be found on the labels of the products. There is thus a serious gap in this area since the lack of rigorous experimental approach might lead to public policies that are not optimized to reduce scorpion populations in urban areas. The WHO [22] recommends a series of procedures for assessing the pesticides that are used to control animals that represent a public health concern (Figure 4). Among the successful measures that have been taken on the basis of this protocol, and which have led to a reduction of infestations and transmission of diseases, it is worth mentioning the chemical control of vectors of the Chagas disease and the use of mosquito nets impregnated with pesticides to combat malaria in Africa [22]. However, this scheme was not adopted to address the problem of spiders and scorpions of public concern. The initial phase of laboratory studies was even more neglected and field studies were generally conducted on the basis of the manufacturers´ recommendations. In reality, what is still needed is the development of an experimental design to make an evaluation of the molecules specific to spiders and scorpions, with good reproducibility. So the comparison of results for different species, or the same species in different regions can be made feasible. Thus, the evaluation of

the methods for testing the susceptibility of the brown spider *L .intermedia* to pyrethroids [11], represents a starting point for improving methods of evaluating the susceptibility of spider and scorpions to pesticides. Here we outline some of the factors that are regarded as necessary for a rigorous validation of a methodology for evaluation of pesticides candidates to use for chemical control of spiders and scorpions in the urban environment.

A) The introduction and maintenance of a reference colony of the target species. In the process of evaluating the susceptibility of a population of organisms, it is strategic to stablish a population sensitive to reduced concentrations of the active principles of biocide molecules. This standard population would allow geographical and temporal comparisons among different regions, evaluating the degree of sensitivity or resistance to a particular product and other parameters. The laboratory colony is vital to carry out evaluations which involves comparing the susceptibility of colonies in the field with that of the laboratory colony and thus, enabling for example, calculation of the resistance ratio (the difference between the LC_{50} of the field population and the LC_{50} of the laboratory population) which has been widely used in studies of the *Aedes Aegypti* populations (Diptera: Culicidae) [190]. In the case of *Loxosceles* and *Latrodectus* spiders, and *Tityus* and other scorpions genera of Buthidae scorpions, the stablishment of these colonies is feasible and of relatively low cost.

B) The age of the population being evaluated. The development stage and age of the organism can result in differences of response to a particular substance. In the lack of availability of a reference colony, it is important to ensure that the organisms being evaluated are at the same stage of development, making replications possible. A suitable number of individuals must be obtained by means of preliminary evaluations. In the case of field populations, an active search for specimens of approximately the same age can be considerably difficult. Obtaining an F_1 generation under laboratory conditions would be a way of overcoming this problem. In both cases, previous studies of the biology of the targeted species being analyzed in the field and laboratory is essential to ensure the reliability of the results obtained in determining the susceptibility of a population to an active principle.

C) The basic information needed in evaluating the potential benefits of products to control spiders and scorpions. The adequate knowledge of the biology, physiology and behavior of the targeted species is useful both for the preparation of analytical experiments under laboratory conditions and in the integrated program control of populations of scorpions and spiders in urban habitats. This information can reduce the likelihood of spiders and scorpions coming into contact with humans in the home environment. It is necessary also to acquire correct understanding of the mechanisms involved and the physiological effects of the substances on the arachnids.

D) Standartization. When a bioassay is conducted to assess the toxicity of molecules on target species creatures such as spiders or scorpions, the results are most suitably expressed not in units of mass, volume or the percentage of the active principle needed to cause lethality, but rather by using solutions of these molecules with concentrations expressed in number of moles per litre, also known as Molarity. If this procedure could become standardized, it would provide an accurate idea of the number of molecules used in each test, information of much greater value than the mass or volume of the pesticide needed to cause the death of these creatures.

The control of organism considered as pests always raises the possibility of analogies with warfare [191] and the pesticides have very often been used in an analogous situation to the use of weapons for the destruction of enemies. However, at present it is clear that practically no pest that is a cause of concern to public health is faced with the prospect of having all its

populations eradicated by man and even less, by means of chemical control only. The damage caused to human health is an aggravating factor that justifies all the attention paid to this issue but it should be stressed that all the organisms regarded as agricultural or urban pests have been able to escape from natural predators and have had access to some form of resource – usually made available by man – which has allowed a rapid growth in population to occur. In the light of this, chemical control is one of the strategies to be employed in integrated pest management programs, with a varying degree of importance that depends on the ecology and behavior of each species and the risks involved to human and environmental health. In the case of spiders and scorpions, as mentioned above, researchers and universities have traditionally tended to downplay the importance of research studies about the ecology and behavior of spiders and scorpions considered to be dangerous to man [192]. In many cases there are not enough rigorous laboratory bioassays to evaluate the effectiveness of pesticides on these organisms. Public health personnel, with a lack of reliable scientific knowledge about the ecology, biology and susceptibility if the target species to pesticides faces the sometimes urgent need to stablish pest management programs to control spiders or scorpions in urban areas. The scientific knowledge and novel management tools are part of the activities that universities and research institutes should be developing [193]. In our view, interaction between the universities and public health authorities is essential to optimize integrated vector management, being chemical control part of these programs.

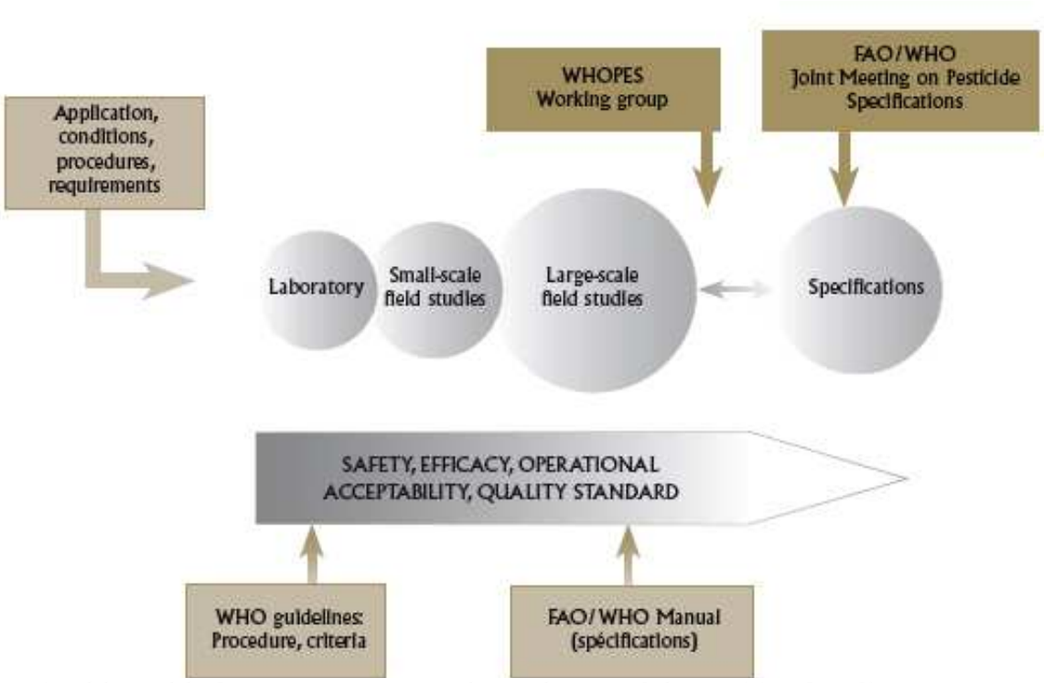


Fig. 4. World Health Organization Pesticide Evaluation Scheme (WHOPES).

5. Perspectives

In countries where synanthropic venomous species of spiders and scorpions that constitute a risk to public health are found, it is urgent the stablishment of a productive, long term form of interaction between the universities and the health managers in the design of bioassays in the laboratory and various small to large scale field studies in the field (Figure

4) [22, 192, 193]. One area still to be explored is the knowledge of mechanisms involved in determining the resistance of spiders and scorpions to pesticides used in urban areas, and to check the possible occurrence of cross resistance with pesticides eventually used in these areas to combat other pests like cockroaches and several species of vector mosquitoes (Dengue, West Nile virus, Malaria, Chagas disease, filariosis) [22]. As has occurred throughout history, in the future the control of spiders and scorpions can continue to benefit from techniques being developed for the control of insect pests and subsequently adapted to these organisms. It has been recognized that RNA interference (RNAi) might be used to ensure that only the target animals are killed, which can be effected by down-regulating the essential gene functions in arthropods [194]. This method may lead to the development of a new generation of species-specific pesticides. Overcoming the specific delivery of dsRNA or siRNA into the cytoplasm of the target cells is still an important issue in the use of RNAi for insecticides [194]. With the increase in the number of genome projects, the RNAi method will be more useful for genome-wide analyses of gene functions. We will then have access to a large pool of info on various insect and other invertebrate genes that may help on the control of arthropods in the real world [195]. Although the use of pheromones already constitutes a very well established area which is recognized for its effectiveness in the integrated control of many insect pests, it has never been used in the control of spiders and scorpions. In spite of ample behavioral evidence of the use of semiochemicals for many species of spiders and scorpions [2, 13, 21], the chemical ecology of the arachnids is still in its initial stage. Only some pheromones have been described for spiders [196] and in the case of scorpions, no substance has been definitively isolated as a semiochemical. However, the sensory apparatus of spiders and scorpions suggests that traps could attract the creatures to relatively short distances, without marked directionality to the olfactory stimulus. In the field of chemical control, several repellents are described for insects. Nonetheless, particularly in the case of scorpions, there are some substances that can act as important chemical barriers to their free passage and also prevent the reinfestation of risk areas. The lack of information and knowledge about the use of these techniques for spiders and scorpions is an impediment in the design of control strategies. In order to identify how the distribution of spiders and scorpions might change as a result of climate warming trend, and to plan vector control strategies, the ecological niche modelling technique can be used, as recently made for *L. reclusa* in the United States [90].

6. Conclusion

The presence of venomous scorpions and spiders in the urban environment can be regarded as a public health hazard that is still being neglected. It is necessary the construction of knowledge in a collaborative network with regard to several factors such as, for example, the biology of the targeted species, the determination of the most suitable molecules, and widely accepted predictive indices as trigger alerts of control measures. The use of microencapsulated formulas seems to be nowadays the most recommended targeting these arachnids, due to lower probability of significant repellency to the animals.

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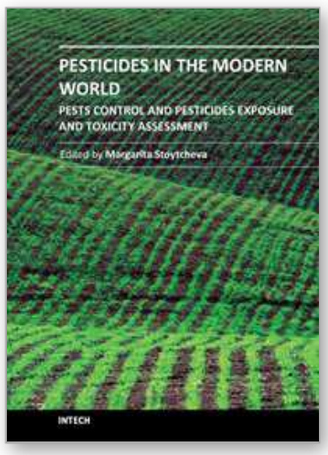
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Pesticides in the Modern World - Pests Control and Pesticides Exposure and Toxicity Assessment

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The present book is a collection of selected original research articles and reviews providing adequate and up-to-date information related to pesticides control, assessment, and toxicity. The first section covers a large spectrum of issues associated with the ecological, molecular, and biotechnological approaches to the understanding of the biological control, the mechanism of the biocontrol agents action, and the related effects. Second section provides recent information on biomarkers currently used to evaluate pesticide exposure, effects, and genetic susceptibility of a number of organisms. Some antioxidant enzymes and vitamins as biochemical markers for pesticide toxicity are examined. The inhibition of the cholinesterases as a specific biomarker for organophosphate and carbamate pesticides is commented, too. The third book section addresses to a variety of pesticides toxic effects and related issues including: the molecular mechanisms involved in pesticides-induced toxicity, fish histopathological, physiological, and DNA changes provoked by pesticides exposure, anticoagulant rodenticides mode of action, the potential of the cholinesterase inhibiting organophosphorus and carbamate pesticides, the effects of pesticides on bumblebee, spiders and scorpions, the metabolic fate of the pesticide-derived aromatic amines, etc.

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