Entomology and Applied Science Letters
Volume 7, Issue 3, Page No: 32-54

Available Online at: www.easletters.com

ISSN No: 2349-2864

Insecticide Resistance in Urban Pests with Emphasis on Urban Pests Resistance in Iran: A Review

Hamid Kassiri [1], Rouhullah Dehghani [2*], Kobra Doostifar [3], Davarkhah Rabbani[2], Mojtaba Limoee[4], Nahid Chaharbaghi[2]

[1] *Department of Medical Entomology, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.*
[2] *Social Determinant of Health (SDH) Research Center and Department of Environment Health, Kashan University of Medical Sciences, Kashan, Iran.*
[3] *Department of Public Health, Shoushtar Faculty of Medical Sciences, Shoushtar, Iran.*
[4] *Department of Public Health and Research Center for Environmental Epidemiology, Kermanshah University of Medical Sciences, Kermanshah, Iran.*

ABSTRACT

Introduction and Objectives: Pests may transmit deadly parasites or pathogens to humans or cause illness, pain and suffering through bites and stings, infected wounds or allergic reactions. Chemical pesticides are considered as the main pest control tool. Insect resistance to the synthetic insecticide occurred following extensive use of this chemical to control pests. Insecticide resistance is a basic threat to urban pest management in the world, to design more applicable Insecticide Resistance Management (IRM) strategies in urban ecosystems. It is necessary to determine the pesticides used for urban pest control and identify various mechanisms underlying insecticide resistance by the pests. **Materials and Methods:** The review search was performed on the medical and health-related literature. Our search strategy provided us with a total of 374 studies, of which 108 of them were excluded and a total of 266 papers were analyzed and presented in this review article. **Results:** The common insecticides used to control four urban insect pests: house fly, German cockroach, mosquitoes and scorpions will be described. We will also discuss different mechanisms cussed resistance developed by these pests. **Conclusions:** The extensive application of insecticides and increasing the pesticide resistance species cause high economic costs and threaten human health. Environment improvement programs to make an undesirable condition for growing arthropods had a reduction effect on the pest population. As well as alternative technologies such as genetic and biological approaches have the potential to control the pest abundance in urban ecosystems. The application of any technology to control the pest to improve human health should not have side-effects on the environment.

Keywords: *Urban Pests, Insecticide, Resistance, Mechanism*

HOW TO CITE THIS ARTICLE: Hamid Kassiri, Rouhullah Dehghani, Kobra Doostifar, Davarkhah Rabbani, Mojtaba Limoee, Nahid Chaharbaghi; Insecticide Resistance in Urban Pests with Emphasis on Urban Pests Resistance in Iran: A Review. Entomol Appl Sci Lett, 2020, 7 (3): 32-54.

Corresponding author: Rouhullah Dehghani
E-mail ✉ dehghani37 @ yahoo.com
Received: 24/03/2020
Accepted: 12/08/2020

INTRODUCTION:

The use of various pesticides to protect crops and control vectors has a long history. The first identified pesticide was sulphur compounds which used about 4500 years ago by the Sumerians to control insects and mites. While about 3200 years ago, arsenical and mercury compounds were utilized by the Chinese to exterminate body lice. The powder of pyrethrum which is gotten from the dried flowers of *Chrysanthemum cinerariaefolium*, as a natural insecticide has been used by Persians for over 2000 years to protect stored grain [1, 2].

The term pesticides include insecticide, herbicide, fungicide, acaricide, molluscicide, nematicide, rodenticide, bactericide, and ovicide. These chemical compounds not only are toxic to pests but are also potentially toxic to other vertebrate and invertebrate organisms, including humans, because of sustainability in nature [3, 4].

Annually, on an average, insects, plant pathogen and weed pests cause damage to more than 40% of all potential food production in agriculture. The application of pesticides to save agricultural production has increased to three million tons by the year in the world. In Iran, about 14,000 tons of agriculture pesticides were annually used [1, 5].

While ecologically, all organisms have their specific functions in the ecosystem, the use of pesticides to control arthropods and other animals as human competitors in the use of agricultural products, or vectors of human diseases can cause bio-ecological degradation [6]. Every year, a large number of pesticides can enter the environment in different ways. According to pesticide solubility, they enter the natural ecosystems. Lipophilic pesticides including chlorines get absorbed in the fatty tissues of animals, resulting in their persistence in food chains for a long time, While Water-soluble pesticides get dissolved in water and enter groundwater, streams, rivers, and lakes, causing environmental contamination and harm effects to untargeted species [1, 7, 8].

Since the production of artificial insecticides and their application in medical programs especially during the world war, the emergence of resistance in insects was a great problem. Most of the researchers did not know that the successive failures in pest control were as a result of pest resistance until 1956 [1].

Insecticidal properties of Dichloro Diphenyl Trichloroethane (DDT) were discovered in 1939 and the malaria eradication program was commenced by the World Health Organization (WHO) in 1955. Initially, the program was greatly successful, but resistance to DDT soon emerged in the insect population including *Anopheles* mosquitoes. Then the goal of eradication was abandoned [9].

Many arthropods including mosquitoes , cockroaches, flies, bedbugs, sucking lice, scorpions, mites and some vertebrates including rodents are major pests that are threats to agriculture and livestock production and human health [10- 26]. A lot of insecticides are used in houses, restaurants, hospitals, hotels and the other infected places in urban environments to control these pest species. Both pest control professionals and homeowners use pesticides in urban environments for medical and agricultural purposes [27]. Repeatedly using the same types of pesticide to control a pest can lead to the pest developing resistance [28]. Resistance to various classes of insecticides is now widespread among medically important insects. This is a basic threat to urban pest management in the world. More than 550 arthropod species have developed some level of resistance to pesticide. [29]. More than 100 species of mosquito (56 *Anopheles* spp., 39 Culicine species) are resistant to at least one insecticide. Findings have shown that, in 60 countries, since 2010, pests have developed resistance to at least one type of insecticide. Fourty-nine countries have reported that the pests have developed a resistance to two or more classes of insecticides [30, 31].

Insecticide resistance phenomena can be varied over time in response to a range of factors, and can also differ greatly over short distances. It is necessary to preserve current insecticides through implementation and development of resistance management strategies. Then identification of insecticides used for urban pest control and mechanisms underlying resistance developed by these arthropods is essential. The present study provides a review on the frequently used insecticides and also the resistance of four common insect pests: German cockroach, house fly, mosquitoes and scorpions to insecticides and the mechanisms of resistance as well, to design more sustainable Insecticide Resistance Management (IRM) strategies pests and decrease the prospect of insecticide resistance in urban regions.

MATERIALS AND METHODS:

This review search was performed on the medical and health-related literature. The databases included MEDLINE, Web of Science, Cochrane Library Database, Google Scholar as well as SID and Iran Medex. Search terms were such as, insecticide, resistance, pesticide, insect, pest, mosquito, housefly, German cockroach, scorpion and Iran to achieve Persian and English pieces of literature from 1978 to 2019. Our search strategy yielded a total of 374 studies, in which 108 of them were excluded after initial screening, because of the lack of relevance to the aims of this study. Totally, 266 searched papers were analyzed and presented in this review article. Ethical subjects (Including plagiarism, double submission and/or publication, redundancy, misbehavior, information fabrication and/or falsification, etc.) have been entirely considered by the researchers. All data were analyzed according to the relevant laws and guidelines of the ethical standards of the Declaration of Helsinki**.**

RESULTS AND DISCUSSION:

Insecticide Resistance in studied urban pests

Houseflies

The housefly, *Musca domestica* Linnaeus, is a well-known cosmopolitan pest of urban ecosystems. This species has an association with humans and livestock for a long time. The house fly found on hog and poultry farms, animal shelters, garbage dumps, and food storage. The housefly is not only an annoyance pest, but also a vector that can transmit more than 100 of animal and human diseases mechanically which are caused by many deadly antibiotic-resistant zoonotic pathogens [32].

Application of chemical insecticides to control *M. Domestica* has a long history which unfortunately leads to a well-documented resistance to many insecticides, including, Organochlorines (OCs), Organophosphates (OPs), Carbamates (CBs) and Pyrethroids (PYs). The housefly is resistant to 62 unique insecticides [28, 33-35].

Resistance to propoxur and malathion in *M. domestica* is associated with cross-resistance to OPs compound used in agriculture. Likewise increased metabolic resistance to DDT is attributed to extreme usage of cypermethrin [36].

Musca domestica has multiple Glutathione S Transferase (GST) genes and the relationship between OPs resistance and GST activity has been reported. Two and probably more of these genes are responsible for elevated GST activity excess transcript in organophosphate insecticide-resistant housefly strain Cornell-R [37]. Resistance to tetrachlorvinphos in this fly is a metabolic resistance in which this OP compound is demethylated by GST [38].

Organophosphate or carbamate resistance in housefly is associated with a reduction in the carboxylesterase activity. Five mutations in the acetylcholinesterase gene (V260L, G342A, G342V, F407Y, and G445A) that either singly or in combination, confer various spectra of insecticide resistance to these chemicals in housefly [33, 39-41]. The kdr insecticide resistance trait in the housefly confers resistance to the rapid paralysis (knockdown) and lethal effects of DDT and PYs. The kdr is the main mechanism for pyrethroid resistance in the *M. Domestica* [42-44].

The important mechanism of resistance to pyrethroid insecticides in the *M. Domestica* that causes target site insensitivity is the mutations in the Voltage-Sensitive Sodium Channel Gene (VSSC). Five known VSSC mutations confer resistance to PYs in the house fly: knockdown resistance (kdr; L1014F), super-kdr (M918T + L1014F) and kdr-his (L1014H), super-kdr (D600N) and kdr (T929I) were found in the resistant housefly. It was discovered that super-kdr + D600N conferred higher levels of resistance to PYs than super-kdr, and kdr + T929I showed super-kdr-like levels of resistance in house flies population [33, 34, 44-49]. Studies showed that the monooxygenase and hydrolase mediated detoxication are involved in resistance to permethrin, beta cypermethrin, cypermethrin, deltamethrin and propoxur in housefly [35].

Application of insecticides to control houseflies in urban environments has resulted in the pests developing resistance to not only four main classes of insecticides but also to biopesticides , Insect Growth Regulators (IGRs), the triazine cyromazine, [50-52] and imidacloprid (neonicotinoid) [53, 54]. The metabolic resistance mechanism was responsible for resistance to this insecticide in the CYR-SEL strain from Punjab, Pakistan [52]. Resistance development to spinosad in the studied field strain of housefly has been reported. The resistance was a recessive trait linked to autosome one, related to an altered target site mechanism, without any cross-resistance with other insecticides (abamectin, deltamethrin, and indoxacarb). These results indicated that spinosad resistance in the housefly is due to a unique mechanism of resistance [55-57]. It was discovered that the neonicotinoid resistance in housefly is associated with the CYP6G4 as an important insecticide resistance gene [58]. It was selected as a strain of housefly that was resistant to indoxacarb following three generations. Resistance was related to major and minor factors on autosomes 4 and 3, respectively [59]. The Imidacloprid resistance is emerging in housefly in Florida, and this species showed tolerance to both imidacloprid and nithiazine [60]. In the results of several studies, it was shown that multiple controlled factors imidacloprid. Resistance to imidacloprid in housefly is autosomally inherited, incompletely recessive and phylogenic [53, 61]. The result of a study revealed that *M. domestica* can develop resistance with continued selection pressure with fipronil. But the level of resistance to lambda-cyhalothrin, profenofos, and indoxacarb did not increase due to this selection. Then there was no cross-resistance to these insecticides [62]. Monooxygenases and esterases mediated fipronil resistance in *M. domestica* have been reported [63]. Likewise the housefly showed the reduced sensitivity to emamectin benzoate, a broad-spectrum agrochemical belonging to the avermectin group of pesticides. The metabolic resistance mechanism does not account for the development of emamectin resistance in the EB-SEL strain [64].

Resistance to pyriproxyfen in the Pyri-SEL strain of the housefly was detected. This resistance in *M. Domestica* was autosomally inherited, completely dominant and polygenic [65, 66].

Mosquitoes

Mosquitoes are the most important vectors of diseases including malaria, lymphatic filariasis , arboviral encephalitis, dengue, and yellow fever. Malaria and dengue fever are the most important mosquito-borne disease. Malaria is transmitted by the female of *Anopheles* mosquito species. In 2015, 212 million cases of malaria occurred worldwide and 429000 deaths from malaria are estimated to have occurred globally, which 303000 cases of them are estimated to have occurred in children aged less than 5 years [67].

The number of reported cases of dengue fever transmitted by *Aedes* species increased from 2.2 million in 2010 to 3.2 million in 2015. The global annual incidence has been estimated at 50 million – 100 million [68]. *Aedes* species are also vectors of yellow fever and chikungunya. Various species of *Culex* are vectors of West Nile, filariasis and mosquito-borne encephalitis [69-72].

Vector control is the most important part of the global approach for the management of mosquito-borne diseases. In this case, one of the very important elements is applying insecticides. Mosquito-borne diseases have become resurgent due to the development of insecticide resistance in mosquito vectors. Six classes of insecticides including OCs, OPs, CBs, PYs, pyrroles, and phenyl pyrazoles are recommended in adult mosquito control programs [73]. Insecticide-Treated Nets (ITNs), Indoor Residual Spraying (IRS) and Long-Lasting Insecticide-Treated Bednets (LLITs) are the insecticide-based approaches for control of adult mosquitoes recommended by WHO. Four main classes of insecticides including, OCs, OPs, CBs, PYs suggested for IRS and the last ones are the only insecticides that are applying for treated bednets according to WHO recommendation [74-81].

The global eradication of malaria was failed soon after the emergence of resistance in the vector mosquitoes to DDT. Then WHO officially switched the program from malaria eradication to malaria control in 1976 [9]. DDT was first applied to control mosquito in 1946. The first mosquito resistance to DDT was reported in *Aedes tritaeniorhynchus* and *Ae. solicitans* in 1947 [82] and *Anopheles sacharovi* in Greece by 1954 [83]. Resistance to DDT or dieldrin had developed in ten confirmed malaria vectors in nineteen countries by the end of 1958 [84]. Since hundreds of mosquito species including 50 Anopheline species were resistant to DDT and at least one or two more insecticides [30]. Findings show that since 2010, the species that have developed resistance to at least one class of insecticide have been reported in 60 countries, fifty of these countries reported resistance to 2 or more classes [85].

The development of insecticide resistance is widespread in mosquitoes and this phenomenon is a global problem for control programs in the world. Resistance to the DDT and dieldrin was reported in mosquito vectors in the world, particularly in malarious areas. Studies detected the resistance of *An. gambiae*, *An. sundaicus*, *An. stephensi*, *An. quadrimaculatus*, *An. subpictus*, *An.*

sacharovi, *Aedes aegypti, Culex fatigans* and *Cu. tarsalis* to these two OCs from 1956 to 1957 [86]. Resistance to DDT, dieldrin in adults of *An. stephensi* has been widespread in the Persian Gulf, the Middle East and Indian-subcontinent areas [87]. Subsequently, the resistance of the other malaria vectors to OCs (DDT, dieldrin, and HCH) was detected from malarious areas including *An. fluviatilis* in Afghanistan, Pakistan, India, and Nepal to DDT, in Saudi Arabia and Pakistan to dieldrin and in India to HCH [87, 88], *An. pulcherrimus* in Afghanistan, Iraq, Saudi Arabia and Syria to DDT, in Afghanistan, and Pakistan to dieldrin [89-91] and *An. sacharovi* population in Turkey [92]. Following the application of the other classes of insecticides in the malaria vector programs, resistance in *Anopheles* species to OPs, CBs, and PYs was detected in numerous countries [93-99]. Widespread resistance to PYs has been reported for malaria vectors from different countries in sub-Saharan Africa as well as central and south-east Asia [95, 100].

The resistance to DDT in *Ae. aegypti* was developed in regions that this vector mosquito distributed. Subsequently, OPs, CBs and Pyrethroid resistance were detected in some regions of the world [87, 101-107]. It was showed that resistance to the OCs in *Ae. aegypti* populations were consistently high while resistance to the CBs was more variable. However resistance to these insecticides has been reported in Asia, Africa, and Latin America and the resistance to PYs in this dengue vector is widespread [108, 109]. Southeast Asia reported the resistance of this vector mosquito population to all four important classes of insecticides although fewer studies assessed the susceptibility of *Ae. albopictus* to insecticides camper to the susceptibility of *Ae. Aegypti.* Resistance to the OPs has also been reported from America [108]. Moderate resistance to new chemical insecticides like imidacloprid and spinosad in *Ae. aegypti* is also reported [110].

In Iran resistance to DDT and deildrin in *An. stephensi*, the main vector of malaria in southern of this country, was first reported from Khuzestan, Fars and Hormozgan Provinces in 1957 and 1960, respectively [111]. Studies have been shown the resistance of this species in Iran to both of these chlorinated insecticides and also fipronil, a phenyl pyrazole insecticide [112-118]. This mosquito vector showed resistance to DDT but a low level of tolerance to dieldrin in southern Iran [119]. The resistance of *An. stephensi* larvae to fenitrothion and tolerance of adults to malathion have been reported from Hormozgan and Fars Provinces of Iran [119-121]. The susceptibility of this major malaria vector to malathion was shown in recent studies in Iran. However the resistance of *An. stephensi* to this insecticide had been reported in 1976, [122] but substituted propoxur in 1978 in malarious areas caused the susceptibility back [117, 123]. The first indication of pyrethroid resistance in *An. stephensi* was reported in a malarious area, from southern Iran [122]. A study carried out in Jask County in the Hormozgan Province southeastern Iran revealed that the field strain of *An. stephensi* was resistant to DDT and lambda-cyhalothrin [124]. Similarly, the resistance of *An. culicifacies* to DDT and dieldrin has been reported from Baluchistan Province, south of Iran [125-127]. The resistance of this malaria vector to deildrin, tolerance to propoxur, and susceptibility to DDT, malathion, and bendiocarb from these areas were reported [126]. The results of a study carried in Hormozgan Province, southern Iran, showed some indication of tolerance to DDT, propoxur, and deltamethrin in this mosquito [117]. The resistance of this species to pyrethroid insecticides was also reported in Baluchistan, Iran [128]. Likewise, *An. maculipennis* vector of malaria in north and central of Iran, showed resistance to DDT [129]. This mosquito species displayed resistance to propoxur, bendiocarb and malathion in West Azarbaijan Province, northwestern Iran, [130] and DDT and deildrin in Astra County, borderline of Iran and Republic of Azarbaijan [131]. The extensive application of DDT against cotton pests in the north part of the country and the other agricultural pesticides in West Azarbaijan Province, known to be able to cause the development of resistance in Anopheline mosquitoes in these areas. The major vector of malaria which is the resistance of *An. sacharovi* to DDT first occurred in 1959 from Kazeroon, subsequently from Izeh and Meshkinshahr, Iran [132]. This species showed resistance to DDT and tolerant to dieldrin in East Azarbaijan Province; Iran; and Borderline of Iran, Armenia, Naxcivan, and Turkey [133, 134]. Resistance to

DDT and deildrin was also detected in *An. Sacharovi* from Ardebil Province, Iran [135]. Similarly, resistance to DDT in an adult of malaria vector *An. d'thali* has been reported from Iran [30].

Culex quinquefasciatus is considered as the main nuisance mosquito in Iran. Transmission of the sindbis virus by *Cx. quinquefasciatus* has been reported in Iran [136]. This species could be a vector of microfilaria, *Dirofilaria immitis* [137]. Studies evaluated the susceptibility of filed strains of *Culex* species revealed the resistance of these mosquitoes to DDT, OPs (chlorpyrifos, malathion), CBs (propoxur) and PYs (deltamethrin ,lambda-cyhalothrin and cyfluthrin) [118, 138-144]. Tolerant to malathion, permethrin, deltamethrin, lambda-cyhalothrin, and etofenprox in this urban species was also reported [118, 143, 145-147**]**.

The two important mechanisms that are involved in insecticide resistance in insects including mosquitoes are target-site insensitivity and increased metabolic detoxification of insecticides. Sodium channels are target-site for insecticides such as DDT and PYs [73, 148, 149] and the reduction of sensitivity of this target site is described by the knockdown resistance (kdr) [108, 150- 152]. By now, kdr mutations have already been reported from African, Asian and, more recently, American continents in at least 13 species: *An. gambiae, An. arabiensis, An. sinensis, An. stephensi, An. subpictus, An. sacharovi, An. culicifacies, An. sundaicus, An. aconitus, An. vagus, An. paraliae, An. peditaeniatus and An. albimanus* [153]. Four mutations (L1014 F/C/S/W), (I1011M/V), (V1016G), and (F1534C) have been correlated with the resistance to these two classes of insecticides in mosquito species [97, 149, 154]. Multiple mutation combinations have been also identified in insecticide resistance mosquitoes including; (L1014F) and (N1575Y) in *An. gambiae*, [155] (V1010L) and (L1014S) in *An. culicifacies* [156], (S989P) and (V1016G), [157] (V1016G) and (D1794Y) [158] and (V1016) and (F1534) in *Ae. aegypti* [159]. The cross-resistance between DDT and PYs which occurred by target-site mutations in the para voltage-gated sodium channel gene kdr, has been detected in several mosquito species [108, 150, 160-163]. A Leu to His amino acid substitution in *An. culicifacies* detected upstream the formerly known knockdown resistance **(**kdr) mutation site in this vector of malaria in Baluchistan of Iran; confer resistance to DDT and PYs [128]. The kdr-type nerve insensitivity mechanism may be involved in resistance to both DDT and deltamethrin insecticides in two strains of *Ae. Aegypti* [164]. Similarly, *Cu. quinquefasciatus* showed high levels of resistance to DDT, permethrin, and deltamethrin [165].

The target site for both OP and carbamate insecticides is Acetylcholinesterase (AChE) which is a key enzyme in the nervous system, hydrolyzing acetylcholine neurotransmitters and terminating nerve impulses [74, 166]. At least five-point mutations in the acetylcholinesterase insecticide-binding site have been identified that singly or in combination are related to resistance to OPs and carbamate insecticides [167]. The γ-Aminobutyric Acid (GABA) receptors are the target for Cyclodiene and fipronil insecticides [168-170].

In addition to mutations at the target site, resistance can also be related to over-expression of certain enzyme families that metabolize or sequester the insecticide molecules, like GST, P450s and esterases [144, 149, 150, 163]. High GST activity has been associated with resistance to all the major classes of insecticides. Detoxification of DDT is catalyzed by GSTs which detected in many insects including *Ae. aegypti*, *An. gambiae* and *An. dirus* [74, 161-165]. GSTs are also responsible for OPs resistance in many insects [171-179].

The other detoxification enzymes, P450s have highly been associated with pyrethroid resistance. The overexpressions of CYP6BB2, CYP9J32, and CYP9J28 have been detected in pyrethroid-resistant strains of *Ae. aegypti* [180, 181]. It was shown that CYP6M2 is an efficient metabolizer of DDT and PYs in the *An. Gambiae* [182, 183]. While CYP6P3 metabolizes PYs [184] and has also potential to metabolize the carbamate, bendiocarb in this vector mosquito [185]. It was detected that the resistance of larvae of *Cx. quinquefasciatus*, *Ae. aegypti* and *An. stephensi* to deltamethrin was mainly due to the detoxification of this pyrethroid insecticide by microsomal mono-oxygenases [186]. The correlation of esterases, monooxygenases and possibly GSTs in pyrethroid resistance of *An.*

stephensi from the south of Iran was confirmed by biochemical assays [187]. The carboxylesterases (CCEs) have been related to resistance to Ops, [188] particularly in *Culex sp* mosquitoes. These enzymes produce resistance through sequestration [189]. The resistance to temephos in *Ae. aegypti* is associated with raised esterase activity [109]. Two CCE genes, CCEae3a and CCEae6a, were detected in temephos resistance strains of *Ae. Albopictus* [149]. Elevated activity of esterases, monooxygenases and glutathione S-transferases in the permethrin resistant than in the susceptible strain of *An. stephensi* was detected, which confer to pyrethroid-resistance in this major vector of malaria in several countries of the Middle East and Indian subcontinent [150]. The existence of behavioral and cuticular resistance in mosquitoes has also been reported [74].

Cockroaches

Cockroaches are considered the most common pests in residential areas and public housing, hospitals, and restaurants. These insects act as mechanical vectors of many, bacteria, fungi, viruses, Protozoa and parasites egg [190]. The German cockroach, *Blattella germanica* (L.) is the most important species of cockroaches which have adapted to human life in cities. The feces, secretions and cast skins originating from the molting process of these urban pests, have allergic substances causing dermatitis, itches and many respiratory disorders. Cockroaches are considered as the second important factor of asthma after dust sensitivities [191].

In 1952, the first insecticide resistance in German cockroaches was reported from the USA against chlordane. Subsequently, Resistance to linden in Poland, linden and dieldrin in Turkey and malathion, diazinon and phenthione in the USA, in 1959, 1962 and 1970s respectively were reported [192]. The German cockroach is resistant to forty-two insecticides of OCs, OPs, and CBs. This species is the No. 2 insecticide-resistant urban pest in the world [193].

Extensive application of four major classes of insecticides including OCs, OPs, CBs, and PYs to control this urban pest, have been led to high-level resistance of *B.germanica* to these insecticides in many field populations. Resistance to DDT, [192, 194], OPs [192, 195-198] CBs [197, 198-201] and PYs, [197,198, 202-205] was reported from different countries in the world. Moderate level of resistance is also found in cockroaches against neonicotinoids (imidacloprid), oxadiazines (indoxacarb) and the phenylpyrazole (fipronil) [198].

In Iran, many studies have been carried out to monitoring insecticides resistance in the German cockroach population from various parts of this country. Resistance to at least four main classes of insecticides has been detected in a field population of this urban pest. Resistance to DDT, [206, 207] OPs, [208-214] CBs [212, 213, 215, 216] and PYs [206-208, 211-213, 214, 217-219] have been reported from various places in different cities of Iran. In German cockroach moderate levels of resistance to fipronil were also discovered [220]. Susceptibility of the *B. germanica* to the spinosad has been reported from Iran [221]. Studies showed the cross-resistance between DDT and pyrethroids in this insect species [197, 207, 208, 217]. Likewise, the limited cross-resistance in DDT and chlordane resistant strains of the German cockroach was observed [195].

The same as the other insects, both target-site insensitivity, and increased metabolic detoxification of insecticides are the two major mechanisms involved in insecticide resistance in cockroaches. It was detected that four-point mutation; glutamic acid to lysine (E434→K434), cysteine to arginine (C764→R764), aspartic acid to glycine (D58→G58), proline to leucine (P1880→L1888) are associated with pyrethroid resistance in cockroaches [222]. Molecular evaluation detected the kdr mutation, the substitution of G for C (L1014F), in collected *B. germanica* from three different locations of Urmia city, northwestern Iran. However, the super-kdr mutation (M918T), was not found in the sequences of the current study [218]. Additional resistance mechanisms such as kdr type and rdl mutation confer to pyrethroids and fipronil resistance in German cockroach [198].

Numerous studies revealed that the metabolic mechanisms were involved in pyrethroid-resistant in German cockroaches which are related to elevated oxidases and esterases in this urban pest [204, 223, 224]. Several studies in Iran also showed the involvement of oxidases, esterases, and GSTs in pyrethroid resistance in *B.germanica* [206, 207, 212]. Multiple

mechanisms of resistance to pyrethroids, including kdr, decreasing of cuticular penetration and elevated metabolism was detected in a strain of German cockroach [222].
Overexpression of GST confers broad-spectrum resistance to a range of OPs and carbamates [225]. Increased level of CYP4G19 is also involved in pyrethroid resistance in *B. germanica* [226]. Studies detected that the detoxification by cytochrome P450s and target site insensitivity, mutation of the alanine to serine (A302S) involved resistance to new chemical insecticides, such as fipronil [227, 228]. Fenvalerate resistance in a strain of *B. germanica* was not omitted by either PBO, MGK-246, or DEF completely. Then additional mechanisms, probably including sodium channel insensitivity, are related to this resistance [229]. Studies revealed that aside from the Leu993Phe mutation in kdr, decreased cuticular penetration may also be involved in cypermethrin resistance in German cockroach [205].

Scorpions

Scorpions are medically important arthropods that are considered as urban pests distributed in a 52N and 5S [230, 231]. In addition to pain caused by a scorpion sting, sometimes it may result in death. Scorpions are predators and feed on other insects or tiny animals. Regarding the variant climate in Iran, a variety of arthropods exist in Iran. Reports showed that there are 59 scorpion species in Iran [232, 233-236]. About 40000-50000 scorpion stings are reported annually from different parts of this country [237, 238].
Scorpions are considered as major pests in the human environment, in the south and southwest of Iran, as well as in some central and eastern parts of this country [239-241]. Different insecticides applied for scorpion control that showed this species are susceptible to insecticide but the continuous use of insecticides may result in resistance [242]. The application of pesticides against scorpions may affect non-target animals including their predators, therefore attention to non-chemical methods to control this arthropod is important [243, 244].

Urban Integrated Pest Management

Arthropods including insects are the most serious threats to the health of humans in the urban ecosystem. The various classes of insecticides have produced in the past fifty years to reduce the pest population. However, Extensive use of insecticides and emphasis on killing pests soon resulted in pesticide-resistant populations of some major insect pests along with some undesirable environmental effects [245]. When only a unique insecticide class is suggested for a particular application, Resistance management is challenging, as is the case of bed [246]. Studies have revealed that Integrated Pest Management (IPM) can be more efficient and successful than conventional pest control [247, 248]. The overall goal of urban IPM is to decrease the pest population while avoiding excessive and ineffective pesticide use [249]. IPM is a combination system of different protection approaches with careful evaluating of pests and their natural enemies to manage them below levels that cause economic damage [250] and endangers human health.
Insecticide resistance monitoring is an essential part of IPM programs. Determination of the susceptibility of pest to insecticides and mechanisms of resistance are the two fundamental points of a pest control program. The molecular methods are preferable since insecticide resistance can be detected before it reaches the maximum level and the insecticide is completely ineffective [251]. Several strategies can be effective to reduce the selection pressure of an insecticide, such as the application of several insecticides in rotation, mixtures, and mosaic formats [252]. Nonchemical techniques like Genetic control should be the powerful new methods that, integrated with current methods to control insect pests [253].
Sterile Insect Technique (SIT) which was introduced in 1955, [254] is one of these methods. By this method, several sterile male mosquitoes (using the irradiation) [255] are released to mate with the wild females which causes a reduction in the reproductive potential. This method is environmentally friendly and is specified for species [28, 256]. SIT has been successfully used to control the New World screwworm (*Cochliomyia hominivorax*) and the Mediterranean fruit fly (*Ceratitis capitata*), tsetse fly (*Glossina fuscipes*) in Zanzibar [257]. Release of engineered male insects that are carriers of a dominant lethal gene (RIDL) to

mate with wild females led to die the progeny [258]. Likewise, Homing Endonuclease Genes (HEGs) is the other molecular and genetic approach to reduce the population of mosquitoes and control mosquito-borne diseases [259, 260].

Biopesticide is the agents produced from living microorganisms or natural products for pest control. These Green chemicals usually have specificity against their target insects with limited impacts on non-target organisms. They are biodegradable with various structures and modes of action, which prohibit the development of resistance. Biopesticides classified as three different types according to the active substance: microorganisms; e.g. *Bacillus thuringiensis*, biochemicals; e.g. pyrethrins, produced by *Chrysanthemum cinerariaefolium*, neem oil, an extract from seeds of *Azadirachta indica*, semiochemicals; e.g. insect sex pheromones [261- 263].

Spinosad is a mixture of two chemicals from *Saccharopolyspora spinosa* which introduced in 1997. The resistance of some pests to this biopesticide has been reported [264]. Similarly, abamectin is a macrocyclic lactone compound produced by *Streptomyces avermitilis*, which resistance has also developed to it in some pests [265].

In recent years, the use of Essential Oils (EOs) derived from aromatic plants has increased to control urban pests. These phytochemicals have repellent, insecticidal, and growth-reducing effects on various species of insects. According to literature, EOs is extracted from different parts of four plant families including Myrtaceae, Lauraceae, Lamiaceae, and Asteraceae [266].

Resistance can be delayed by strategies such as responsive alternation, mosaic, periodic application, and combinations. Other strategies such as cultural and biological control and also environment improvement techniques should also be considered in resistance management programs Education of the residents should be an important component of an IPM program. It was reported that educational programs had a positive impact on residents' attitudes [252].

CONCLUSIONS:

The extensive application of insecticides and increasing the pesticide resistance species cause high economic costs and threaten human health. Then the evaluation of resistance to different classes of insecticides in urban pests as well as understanding the mechanism of resistance in these arthropods are necessary to apply the best strategy in IPM programs to control them in urban ecosystems. In this regard, recognizing the biology and ecology of pests is an important issue.

Environment improvement programs to make an undesirable condition for growing arthropods had a reduction effect on the pest population. As well as alternative technologies such as genetic and biological approaches have the potential to control the pest abundance in urban ecosystems. The application of any technology to control the pest to improve human health should not have adverse effects on the environment.

ACKNOWLEDGEMENTS:

Authors would like to thank Research Health vice-chancellery of Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran and Kashan University of Medical Sciences, Kashan, Iran for their cooperation.

Ethics Approval:

All data were analyzed according to the relevant laws and guidelines of the ethical standards of the Declaration of Helsinki.

Conflict of Interest Statement:

The authors declare that they have no competing interests.

Financial Disclosure:

There were no sources of extra-institutional commercial findings.

Funding/Support:

This research did not receive any specific grants from any funding agencies in the public, commercial or not-for-profit sectors.

Authors' Contribution:

All authors participated in the research design and contributed to different parts of the research.

REFERENCES:

1. Dehghani R. Environmental toxicology Publications of Tak Derakhat and Kashan University of Medical Sciences. Sci J Kurdistan Univ Med Sci. 2010;17(1):172-206.
2. Gharagazlooa F, Akbarib H, Dehghania R, Rabbania D. Investigation of diazinon toxicity of water treated with electrochemical process using Daphnia magna. Desalination and Water treatment. 2017 Sep 1:1-6.
3. Dehghani R, Limoee M, Zarghi I. The review of pesticide hazards with emphasis on insecticide resistance in arthropods of health risk importance. Scientific Journal of Kurdistan University of Medical Sciences. 2012 Apr 10;17(1):82-98.
4. Mostafaii G, Dehghani R, Najafi M, Moosavi G, Rajaei M, Moghadam VK, Takhtfiroozeh S. Frequency of urban pests and pesticides consumption in the residential houses of the east of Tehran city, Iran. Journal of Entomological Research. 2017;41(2):125-32.
5. Morteza Z, Mousavi SB, Baghestani MA, Aitio A. An assessment of agricultural pesticide use in Iran, 2012-2014. Journal of Environmental Health Science and Engineering. 2017 Dec 1;15(1):10.
6. Dehghani R, Shahrisvand B, Mostafaeii G, Atharizadeh M, Gilasi H, Mofrad MR, Hosseindoost G, Takhtfiroozeh S. Frequency of Arthropoda in urban Wastes compost Process at Laboratory condition. Journal of Entomological Research. 2016;40(4):357-64.
7. Dehghani R, Moosavi G, Takhtfiroozeh SM, Rashedi G. Investigation of the removal of cyanide from aqueous solutions using biomass Saccharomyces cerevisiae. Desalination and Water Treatment. 2016 Dec 1;57(56):27349-54.
8. Mahmood I, Imadi SR, Shazadi K, Gul A, Hakeem KR. Effects of pesticides on environment. InPlant, soil and microbes 2016 (pp. 253-269). Springer, Cham.
9. Bradley DJ. The particular and the general. Issues of specificity and verticality in the history of malaria control. Parassitologia. 1998 Jun;40(1-2):5-10.
10. Dehghani R, Miranzadeh MB, Yosefzadeh M, Zamani S. Fauna aquatic insects in sewage maturation ponds of Kashan University of Medical Science 2005. Pakistan journal of biological sciences. 2007 Mar 15;10(6):928-31.
11. Vazirianzadeh B, Dehghani R, Mehdinejad M, Sharififard M, Nasirabadi N. The first report of drug resistant bacteria isolated from the brown-banded cockroach, Supella longipalpa, in ahvaz, south-western Iran. Journal of arthropod-borne diseases. 2014;8(1):53-9.
12. Vazirianzadeh B, MAHDINEZHAD M, Dehghani R. Identification of bacteria which possible transmitted by Polyphaga aegyptica (Blattodea: Blattidae) in the region of Ahvaz, SW Iran. Jundishapur J Microbiol 2009;2:36–40 .
13. Dehghani R, Kassiri H, Gharali B, Hoseindoost G, Chimehi E, Takhtfiroozeh S, Moameni M. Introducing of a new sting agent of velvet ant dentilla sp.(hymenoptera: Mutillidae) in Kashan, centerl of Iran (2014-2015). Archives of Clinical Infectious Diseases. 2018;13(6): e60553.
14. Rasti S, Dehghani R, Khaledi HN, Takhtfiroozeh SM, Chimehi E. Uncommon human urinary tract myiasis due to Psychoda sp. Larvae, Kashan, Iran: A case report. Iranian journal of parasitology. 2016 Jul;11(3):417-21.
15. Dehghani R, Sedaghat MM, Bidgoli MS. Wound myiasis due to Musca domestica (Diptera: Muscidae) in Persian horned viper, Pseudocerastes persicus (Squamata: Viperidae). Journal of arthropod-borne diseases. 2012;6(1):86-89.
16. Dehghani R, Takhtfiroozeh M, Kanani F, Aslani S. Case report of Stomoxys calcitrans bites in residential area of Kashan, Iran. Journal of Mazandaran University of Medical Sciences. 2014 Mar 15;23(110):257-61.
17. Dehghani R, Zarghi I, Sayyedi HR. Genital myiasis of a sheep by Wohlfahrtia magnifica, in Ghamsar, Kashan, Iran. Bangladesh Journal of Medical Science. 2014 Jun 6;13(3):332-5.
18. Motevalli Haghi F, Dehghani R. A review of scorpions reported in Iran. Journal of Mazandaran University of Medical Sciences. 2017 Aug 15;27(151):213-26.
19. Dehghani R, Hashemi A, Takhtfiroozeh S, Chimehi E. Bed bug (Cimex lectularis) outbreak: A cross-sectional study in Polour, Iran. Iran J. Dermatol. 2016;19:16-20.

20. Dehghani R, Limoee M, Ahaki A. Research Note First report of family infestation with pubic louse (Pthirus pubis; Insecta: Anoplura: Pthiridae) in Iran–a case report. Tropical biomedicine. 2013;30(1):152-4.
21. Kamiabi F, Nakhaei FH. Prevalence of pediculosis capitis and determination of risk factors in primary-school children in Kerman. EMHJ-Eastern Mediterranean Health Journal, 11 (5-6), 988-992, 2005. 2005; 11(5-6): 988-992.
22. Dehghani R, Hoseindoost G, Bidgoli NS, Zamani M, Ghadami F. Study on pests of residential complex and student dormitories of Kashan University of Medical Sciences, Iran. Journal of Entomological Research. 2017;41(3):311-6.
23. Dehghani R, Djadid ND, Shahbazzadeh D, Bigdelli S. Introducing Compsobuthus matthiesseni (Birula, 1905) scorpion as one of the major stinging scorpions in Khuzestan, Iran. Toxicon. 2009 Sep 1;54(3):272-5.
24. DEHGHANI R, Vazirianzadeh B, Hejazi SH, Jalayer N. Frequency of Sarcoptes scabiei infestation in patients referred to the parasitology laboratory in Isfahan, Iran (1996-2002);2: 65-70.
25. Dehghani R, Vazirianzadeh B, Asadi MA, Akbari H, Moravvej SA. Infestation of Rodents (Rodentia: Muridae) Among Houses in Kashan, Central Iran. Pakistan journal of zoology. 2012 Dec 1;44(6):1721-6.
26. Dehghani R, Rafinejad J, Fathi B, Shahi MP, Jazayeri M, Hashemi A. A retrospective study on Scropionism in Iran (2002–2011). Journal of arthropod-borne diseases. 2017 Jun;11(2):194.
27. Zarrintab M, Mirzaei R, Mostafaei G, Dehghani R, Akbari H. Concentrations of metals in feathers of magpie (Pica pica) from aran-O-bidgol city in central Iran. Bulletin of environmental contamination and toxicology. 2016 Apr 1;96(4):465-71.
28. Zhu F, Lavine L, O'Neal S, Lavine M, Foss C, Walsh D. Insecticide resistance and management strategies in urban ecosystems. Insects. 2016 Mar;7(1):2.
29. Hoy MA. Myths, models and mitigation of resistance to pesticides. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences. 1998 Oct 29;353(1376):1787-95.
30. WHO Expert Committee on Vector Biology and Control. Vector resistance to insecticides, 15th Report. World Health Organization Technology Report Series 1992; 818: 1-62.
31. WHO, Q&A on the Global plan for insecticide resistance management in malaria vectors, October 2016, http://www.who.int/malaria/media/insecticide_resistance_management_qa/en/
32. Sarwar M. Life History of House Fly Musca domestica Linnaeus (Diptera: Muscidae), its Involvement in Diseases Spread and Prevention of Vector. International Journal For Research In Applied And Natural Science. 2016 Jul 31;2(7):31-42.
33. Wang Q, Li M, Pan J, Di M, Liu Q, Meng F, Scott JG, Qiu X. Diversity and frequencies of genetic mutations involved in insecticide resistance in field populations of the house fly (Musca domestica L.) from China. Pesticide biochemistry and physiology. 2012 Feb 1;102(2):153-9.
34. Scott JG, Leichter CA, Rinkevihc FD, Harris SA, Su C, Aberegg LC, Moon R, Geden CJ, Gerry AC, Taylor DB, Byford RL. Insecticide resistance in house flies from the United States: Resistance levels and frequency of pyrethroid resistance alleles. Pesticide biochemistry and physiology. 2013 Nov 1;107(3):377-84.
35. Liu N, Yue X. Insecticide resistance and cross-resistance in the house fly (Diptera: Muscidae). Journal of economic entomology. 2000 Aug 1;93(4):1269-75.
36. Bong LJ, Zairi J. Temporal fluctuations of insecticides resistance in Musca domestica Linn (Diptera: Muscidae) in Malaysia. Tropical Biomedicine. 2010 Aug 1;27(2):317-25.
37. Wang JY, McCommas S, Syvanen M. Molecular cloning of a glutathione S-transferase overproduced in an insecticide-resistant strain of the housefly (Musca domestica). Molecular and General Genetics MGG. 1991 Jun 1;227(2):260-6.
38. Oppenoorth FJ, Van der Pas LJ, Houx NW. Glutathione S-transferase and hydrolytic activity in a tetrachlorvinphos-resistant strain of housefly and their influence on resistance. Pesticide Biochemistry and Physiology. 1979 Jul 1;11(1-3):176-88.

39. Kozaki T, Brady SG, Scott JG. Frequencies and evolution of organophosphate insensitive acetylcholinesterase alleles in laboratory and field populations of the house fly, Musca domestica L. Pesticide biochemistry and physiology. 2009 Sep 1;95(1):6-11.
40. Walsh SB, Dolden TA, Moores GD, Kristensen M, Lewis T, Devonshire AL, Williamson MS. Identification and characterization of mutations in housefly (Musca domestica) acetylcholinesterase involved in insecticide resistance. Biochemical Journal. 2001 Oct 1;359(1):175-81.
41. Başkurt S, Taşkın BG, Doğaç E, Taşkın V. Polymorphism in the acetylcholinesterase gene of Musca domestica L. field populations in Turkey. Journal of Vector Ecology. 2011 Dec;36(2):248-57.
42. Huang J, Kristensen M, Qiao CL, Jespersen JB. Frequency of kdr gene in house fly field populations: correlation of pyrethroid resistance and kdr frequency. Journal of economic entomology. 2004 Jun 1;97(3):1036-41.
43. Knipple DC, Doyle KE, Marsella-Herrick PA, Soderlund DM. Tight genetic linkage between the kdr insecticide resistance trait and a voltage-sensitive sodium channel gene in the house fly. Proceedings of the National Academy of Sciences. 1994 Mar 29;91(7):2483-7.
44. Al-Deeb MA. Pyrethroid insecticide resistance kdr gene in the house fly, Musca domestica (Diptera: Muscidae), in the United Arab Emirates. Agricultural Sciences. 2014 Dec 9;5(14):1522.
45. Rinkevich FD, Hedtke SM, Leichter CA, Harris SA, Su C, Brady SG, Taskin V, Qiu X, Scott JG. Multiple origins of kdr-type resistance in the house fly, Musca domestica. PLoS One. 2012;7(12): e52761.
46. Rinkevich FD, Zhang L, Hamm RL, Brady SG, Lazzaro BP, Scott JG. Frequencies of the pyrethroid resistance alleles of Vssc1 and CYP6D1 in house flies from the eastern United States. Insect molecular biology. 2006 Apr;15(2):157-67.
47. Liu N, Pridgeon JW. Metabolic detoxication and the kdr mutation in pyrethroid resistant house flies, Musca domestica (L.). Pesticide biochemistry and physiology. 2002 Jul 1;73(3):157-63.
48. Sun H, Kasai S, Scott JG. Two novel house fly Vssc mutations, D600N and T929I, give rise to new insecticide resistance alleles. Pesticide biochemistry and physiology. 2017 Nov 1;143:116-21.
49. Rinkevich FD, Leichter CA, Lazo TA, Hardstone MC, Scott JG. Variable fitness costs for pyrethroid resistance alleles in the house fly, Musca domestica, in the absence of insecticide pressure. Pesticide biochemistry and physiology. 2013 Mar 1;105(3):161-8.
50. Acevedo GR, Zapater M, Toloza AC. Insecticide resistance of house fly, Musca domestica (L.) from Argentina. Parasitology research. 2009 Jul 1;105(2):489-93.
51. Bell HA, Robinson KA, Weaver RJ. First report of cyromazine resistance in a population of UK house fly (Musca domestica) associated with intensive livestock production. Pest management science. 2010 Jul;66(7):693-5.
52. Khan HA, Akram W. Cyromazine resistance in a field strain of house flies, Musca domestica L.: Resistance risk assessment and biochemical mechanism. Chemosphere. 2017 Jan 1;167:308-13.
53. Memmi BK. Mortality and knockdown effects of imidacloprid and methomyl in house fly (Musca domestica L., Diptera: Muscidae) populations. Journal of Vector Ecology. 2010 Jun;35(1):144-8..
54. Khan H, Abbas N, Shad SA, Afzal MB. Genetics and realized heritability of resistance to imidacloprid in a poultry population of house fly, Musca domestica L.(Diptera: Muscidae) from Pakistan. Pesticide biochemistry and physiology. 2014 Sep 1;114:38-43.
55. Khan HA, Akram W, Shad SA. Genetics, cross-resistance and mechanism of resistance to spinosad in a field strain of Musca domestica L.(Diptera: Muscidae). Acta Tropica. 2014 Feb 1;130:148-54.
56. Højland DH, Jensen KM, Kristensen M. Expression of xenobiotic metabolizing cytochrome P450 genes in a spinosad-resistant Musca domestica L. strain. PLoS One. 2014;9(8): e103689.
57. Shono T, Scott JG. Spinosad resistance in the housefly, Musca domestica, is due to a recessive factor on autosome 1. Pesticide Biochemistry and Physiology. 2003 Jan 1;75(1-2):1-7.

58. Højland DH, Vagn Jensen KM, Kristensen M. A comparative study of P450 gene expression in field and laboratory Musca domestica L. strains. Pest management science. 2014 Aug;70(8):1237-42.
59. Shono T, Zhang L, Scott JG. Indoxacarb resistance in the house fly, Musca domestica. Pesticide Biochemistry and Physiology. 2004 Oct 1;80(2):106-12.
60. Kaufman PE, Nunez SC, Mann RS, Geden CJ, Scharf ME. Nicotinoid and pyrethroid insecticide resistance in houseflies (Diptera: Muscidae) collected from Florida dairies. Pest Management Science: formerly Pesticide Science. 2010 Mar;66(3):290-4.
61. Kaufman PE, Gerry AC, Rutz DA, Scott JG. Monitoring susceptibility of house flies (Musca domestica L.) in the United States to imidacloprid. J. Agric. Urban Entomol. 2006 Oct 1;23(4):195-200.
62. Abbas N, Ijaz M, Shad SA, Binyameen M. Assessment of resistance risk to fipronil and cross resistance to other insecticides in the Musca domestica L.(Diptera: Muscidae). Veterinary parasitology. 2016 Jun 15;223:71-6.
63. Abbas N, Khan HA, Shad SA. Cross-resistance, genetics, and realized heritability of resistance to fipronil in the house fly, Musca domestica (Diptera: Muscidae): a potential vector for disease transmission. Parasitology research. 2014 Apr 1;113(4):1343-52.
64. Khan HA, Akram W, Khan T, Haider MS, Iqbal N, Zubair M. Risk assessment, cross-resistance potential, and biochemical mechanism of resistance to emamectin benzoate in a field strain of house fly (Musca domestica Linnaeus). Chemosphere. 2016 May 1;151:133-7.
65. Shah RM, Shad SA, Abbas N. Mechanism, stability and fitness cost of resistance to pyriproxyfen in the house fly, Musca domestica L.(Diptera: Muscidae). Pesticide biochemistry and physiology. 2015 Mar 1;119:67-73.
66. Shah RM, Abbas N, Shad SA, Varloud M. Inheritance mode, cross-resistance and realized heritability of pyriproxyfen resistance in a field strain of Musca domestica L.(Diptera: Muscidae). Acta tropica. 2015 Feb 1;142:149-55.
67. WHO, World malaria report 2016, ISBN 978-92-4-151171-1, 150P.
68. WHO, Weekly epidemiological record, 29 July 2016c, 91th year, No 30, 2016, 91, 349–364,http://www.who.int/wer.
69. WHO, West Nile virus , Fact sheet NO 354, July 2011 http://www.who.int/mediacentre/factsheets/fs354/en/.
70. Eastwood G, Kramer LD, Goodman SJ, Cunningham AA. West Nile virus vector competency of Culex quinquefasciatus mosquitoes in the Galápagos Islands. The American journal of tropical medicine and hygiene. 2011 Sep 1;85(3):426-33.
71. WHO, Japanese encephalitis, Fact sheet No 386, December 2015 http://www.who.int/mediacentre/factsheets/fs386/en/.
72. Tiawsirisup S, Nuchprayoon S. Mosquito distribution and Japanese encephalitis virus infection in the immigration bird (Asian open-billed stork) nested area in Pathum Thani province, central Thailand. Parasitology research. 2010 Mar 1;106(4):907-10.
73. Liu N. Insecticide resistance in mosquitoes: impact, mechanisms, and research directions. Annual review of entomology. 2015 Jan 7;60:537-59.
74. WHO. Global Plan for Insecticide Resistance Management in Malaria Vectors (GPIRM); WHO: Geneva, Switzerland, 2012.
75. Hemingway J. The role of vector control in stopping the transmission of malaria: threats and opportunities. Philosophical Transactions of the Royal Society B: Biological Sciences. 2014 Jun 19;369(1645):20130431. Doi.org/10.1098/rstb.2013.0431
76. Nauen R. Insecticide resistance in disease vectors of public health importance. Pest Management Science: formerly Pesticide Science. 2007 Jul;63(7):628-33.
77. Hemingway J, Ranson H. Insecticide resistance in insect vectors of human disease. Annual review of entomology. 2000 Jan;45(1):371-91.
78. WHO: Global Malaria Action Plan. 2008, **www.unhcr.org/4afac5629.pdf** Switzerland
79. WHO: Roll Back Malaria Global Strategic Plan 2005-2015, 2005.

80. WHO. World Malaria Report 2009, 66P.
81. WHO: Indoor residual spraying: Use of indoor residual spraying for scaling up malaria control and elimination World Health Organization/Roll Back Malaria; 2006.
82. Brown AW. Insecticide resistance in mosquitoes: a pragmatic review. Journal of the American Mosquito Control Association. 1986 Jun;2(2):123-40.
83. Brogdon WG, Fiore A, Kachur SP, Slutsker L, Wirtz RA. Insecticide resistance and malaria. A Threat Decades in the Making. Washington, DC. 2014 Dec;20036:1-6.
84. de Zulueta J. Insecticide resistance in Anopheles sacharovi. Bulletin of the World Health Organization. 1959;20(5):797-822.
85. WHO, Insecticide resistance, Last update: 7 November 2017 http://www.who.int/malaria/areas/vector_control/insecticide_resistance/en/
86. Brown AW. The insecticide-resistance problem: a review of developments in 1956 and 1957. Bulletin of the World Health Organization. 1958;18(3):309-21.
87. WHO, Resistance of vectors of disease to pesticides. Tenth report of the expert committee on vector control. Tech. rep. series, No, 734, Geneva, 1985.
88. Sahu SS, Patra KP. A study on insecticide resistance in Anopheles fluviatilis and anopheles culicifacies to HCH and DDT in the Malkangiri district of Orissa. Indian journal of malariology. 1995 Sep;32(3):112-8.
89. WHO: Meeting report on the regional workshop on integrated vector control. Lahor, Pakistan, 14-19 October, 1995. WHO - EM/VBC/82/E/L, 1997
90. Manoucheri AV, Shalli AK, Al-Saadi SH, Al-Okaily AK. Status of resistance of anopheline mosquitoes in Iraq, 1978. Mosq. News. 1980 Jan 1;40:535-40.
91. Onori E, Nushin MK, Cullen JE, Yakubi GH, Mohammed K, Christal FA. An epidemiological assessment of the residual effect of DDT on Anopheles hyrcanus sensulato and A. pulcherrimus (Theobold) in the North eastern region of Afghanistan. Transactions of the Royal Society of Tropical Medicine and Hygiene. 1975 Jan 1;69(2):236-42.
92. Hemingway J, Small GJ, Monro A, Sawyer BV, Asap HK. Insecticide resistance gene frequencies in Anopheles sacharovi populations of the Cukurova plain, Adana Province, Turkey. Medical and veterinary entomology. 1992 Oct;6(4):342-8.
93. Cui F, Raymond M, Qiao CL. Insecticide resistance in vector mosquitoes in China. Pest Management Science: formerly Pesticide Science. 2006 Nov;62(11):1013-22.
94. Ranson H, Abdallah H, Badolo A, Guelbeogo WM, Kerah-Hinzoumbé C, Yangalbé-Kalnoné E, Simard F, Coetzee M. Insecticide resistance in Anopheles gambiae: data from the first year of a multi-country study highlight the extent of the problem. Malaria journal. 2009 Dec;8(1):299.
95. Ranson H, N'guessan R, Lines J, Moiroux N, Nkuni Z, Corbel V. Pyrethroid resistance in African anopheline mosquitoes: what are the implications for malaria control?. Trends in parasitology. 2011 Feb 1;27(2):91-8.
96. Casimiro S, Coleman M, Hemingway J, Sharp B. Insecticide resistance in Anopheles arabiensis and Anopheles gambiae from Mozambique. Journal of medical entomology. 2014 Oct 24;43(2):276-82.
97. Hunt RH, Fuseini G, Knowles S, Stiles-Ocran J, Verster R, Kaiser ML, Choi KS, Koekemoer LL, Coetzee M. Insecticide resistance in malaria vector mosquitoes at four localities in Ghana, West Africa. Parasites & vectors. 2011 Dec 1;4(1):107.
98. Sumarnrote A, Overgaard HJ, Marasri N, Fustec B, Thanispong K, Chareonviriyaphap T, Corbel V. Status of insecticide resistance in Anopheles mosquitoes in Ubon Ratchathani province, Northeastern Thailand. Malaria journal. 2017 Dec;16(1):299.
99. Kasap H, Kasap M, Alptekin D, Lüleyap Ü, Herath PR. Insecticide resistance in Anopheles sacharovi Favre in southern Turkey. Bulletin of the World Health Organization. 2000;78:687-92.
100. Mulamba C, Riveron JM, Ibrahim SS, Irving H, Barnes KG, Mukwaya LG, Birungi J, Wondji CS. Widespread pyrethroid and DDT resistance in the major malaria vector Anopheles funestus in East Africa is driven by metabolic resistance mechanisms. PloS one. 2014;9(10):e110058.
101. Rodríguez MM, Bisset J, Ruiz M, Soca A. Cross-resistance to pyrethroid and organo-

phosphorus insecticides induced by selection with temephos in Aedes aegypti (Diptera: Culicidae) from Cuba. Journal of medical entomology. 2002 Nov 1;39(6):882-8.
102. Mazzarri MB, Georghiou GP. Characterization of resistance to organophosphate, carbamate, and pyrethroid insecticides in field populations of Aedes aegypti from Venezuela. Journal of the American Mosquito Control Association-Mosquito News. 1995 Sep 1;11(3):315-22.
103. Marcombe S, Mathieu RB, Pocquet N, Riaz MA, Poupardin R, Sélior S, Darriet F, Reynaud S, Yebakima A, Corbel V, David JP. Insecticide resistance in the dengue vector Aedes aegypti from Martinique: distribution, mechanisms and relations with environmental factors. PloS one. 2012;7(2):e30989.
104. Dusfour I, Thalmensy V, Gaborit P, Issaly J, Carinci R, Girod R. Multiple insecticide resistance in Aedes aegypti (Diptera: Culicidae) populations compromises the effectiveness of dengue vector control in French Guiana. Memorias do Instituto Oswaldo Cruz. 2011 May;106(3):346-52.
105. Hamdan H, Sofian-Azirun M, Nazni WA, Lee HL. Insecticide resistance development in Culex quinquefasciatus (Say), Aedes aegypti (L.) and Aedes albopictus (Skuse) larvae against malathion, permethrin and temephos. Trop Biomed. 2005 Jun 1;22(1):45-52.
106. Macoris MD, Andrighetti MT, Takaku L, Glasser CM, Garbeloto VC, Bracco JE. Resistance of Aedes aegypti from the state of São Paulo, Brazil, to organophosphates insecticides. Memórias do Instituto Oswaldo Cruz. 2003 Jul;98(5):703-8.
107. Sathantriphop S, Paeporn P, Supaphathom K. Detection of insecticides resistance status in Culex quinquefasciatus and Aedes aegypti to four major groups of insecticides. Trop Biomed. 2006 Jun 1;23(1):97-101.
108. Moyes CL, Vontas J, Martins AJ, Ng LC, Koou SY, Dusfour I, Raghavendra K, Pinto J, Corbel V, David JP, Weetman D. Contemporary status of insecticide resistance in the major Aedes vectors of arboviruses infecting humans. PLoS neglected tropical diseases. 2017 Jul;11(7): e0005625.
109. WHO, Management of insecticide resistance in vectors of public health importance report of the ninth meeting of the global collaboration for development of pesticides for public health 9–10 September 2014 , 52P
110. Paul A, Harrington LC, Scott JG. Evaluation of novel insecticides for control of dengue vector Aedes aegypti (Diptera: Culicidae). Journal of Medical Entomology. 2006 Jan 1;43(1):55-60.
111. Brown AW, Pal R. Insecticide resistance in arthropods. World Health Organization. Monogr Ser 1971; 38: 95-143.
112. Manouchehri AV, Eshghi N, Rouhani. Malathion susceptibility test of Anopheles stephensi mysorensis in southern Iran. Mosq News 1974; 34: 440–442.
113. Manouchehri AV, Djanbakhsh B, Eshghi N. The biting cycle of Anopheles dthali. A. fluviatilis and A. stephensi in southern Iran. Tropical and geographical medicine. 1976 Sep;28(3):224-7.
114. Manouchehri AV, Javadian E, Eshighy N, Motabar M. Ecology of Anopheles stephensi Liston in southern Iran. Trop Geogr Med. 1976 Sep;28(3):228-32.
115. Davari B, Vatandoost H, Oshaghi MA, Ladonni H, Enayati AA, Shaeghi M, Basseri HR, Rassi Y, Hanafi-Bojd AA. Selection of Anopheles stephensi with DDT and dieldrin and cross-resistance spectrum to pyrethroids and fipronil. Pesticide Biochemistry and Physiology. 2007 Oct 1;89(2):97-103.
116. Davari B, Vatandoost H, Ladonni H, Shaeghi M, Oshaghi MA, Basseri HR, Enayati AA, Rassi Y, Abai MR, Hanfi-Bojd AA, Akbarzadeh K. Comparative Efficacy of Different Imagicides Against Different Strains of Anopheles stephensi in the Malarious Areas of Iran, 2004—2005. Pakistan J Biolog Sci. 2006;9(5):885-92.
117. Hanafi-Bojd AA, Vatandoost H, Oshaghi MA, Haghdoost AA, Shahi M, Sedaghat MM, Abedi F, Yeryan M, Pakari A. Entomological and epidemiological attributes for malaria transmission and implementation of vector control in southern Iran. Acta tropica. 2012 Feb 1;121(2):85-92.
118. Fathian M, Vatandoost H, Moosa-Kazemi SH, Raeisi A, Yaghoobi-Ershadi MR, Oshaghi MA, Sedaghat MM. Susceptibility of Cu-

licidae mosquitoes to some insecticides recommended by WHO in a malaria endemic area of southeastern Iran. Journal of arthropod-borne diseases. 2015 Jun;9(1):22-34.
119. Vatandoost H, Oshaghi MA, Abaie MR, Shahi M, Yaaghoobi F, Baghaii M, Hanafi-Bojd AA, Zamani G, Townson H. Bionomics of Anopheles stephensi Liston in the malarious area of Hormozgan province, southern Iran, 2002. Acta Tropica. 2006 Feb 1;97(2):196-203.
120. Eshghy N. Tolerance of Anopheles stephensi to malathion in the province of Fars, Southern Iran 1977. Mosq. News. 1978 Jan 1;38(4):580-3.
121. Vatandoost H, Shahi H, Abai MR, Hanafi-Bojd AA, Oshaghi MA, Zamani G. Larval habitats of main malaria vectors in Hormozgan province and their susceptibility to different larvicides. Southeast Asian J Trop Med Public Health. 2004;35(2):22-5.
122. Vatandoost H, Hanafi-Bojd AA. Indication of pyrethroid resistance in the main malaria vector, Anopheles stephensi from Iran. Asian Pacific journal of tropical medicine. 2012 Sep 1;5(9):722-6.
123. Iranpour M, Yaghoobj-Ershadi MR, Motabar M. Susceptibility Tests of Anopheles Stephensi with Some Chlorine, Phosphorus, Carbamate and Pyretilroid Insecticicdes In South Of Iran. Iranian Journal of Public Health. 1993:74-85.
124. Zare M, Soleimani-Ahmadi M, Davoodi SH, Sanei-Dehkordi A. Insecticide susceptibility of Anopheles stephensi to DDT and current insecticides in an elimination area in Iran. Parasites & vectors. 2016 Dec;9(1):571.
125. . Zaini A, Manouchehri AV. PRELIMINARY NOTES ON THE DEVELOPMENT OF DDT RESISTANCE IN ANOPHELES CULICIFACIES. Iranian Journal of Public Health. 1973:156-62.
126. Vatandoost H, Nateghpour AZ. Status of insecticide resistance in Anopheles culicifacies (Diptera: culicidae) in Ghasreghand district, Sistan and Baluchistan Province, Iran,(1997). Acta Medica Iranica. 1999:128-33.
127. Manoucheri AV, Zaini A, Javadian E. Resistance of Anopheles culicifacies Giles to DDT in Baluchestan Province, Southern Iran, 1974. Mosq News. 1975 Jan 1;35(3):314-6.
128. Dinparast Djadid N, Forouzesh F, Karimi M, Raeisi A, Hassan-Zehi A, Zakeri S. Monitoring pyrethroid insecticide resistance in major malaria vector Anopheles culicifacies: comparison of molecular tools and conventional susceptibility test. Iranian Biomedical Journal. 2007 Jul 10;11(3):169-76.
129. Manouchehri AV, Zaini A, Motaghi M. Susceptibility of Anopheles maculipennis to insecticides in northern Iran, 1974. Mosquito News. 1976;36(1):51-5.
130. Chavshin AR, Dabiri F, Vatandoost H, Bavani MM. Susceptibility of Anopheles maculipennis to different classes of insecticides in West Azarbaijan Province, Northwestern Iran. Asian Pacific Journal of Tropical Biomedicine. 2015 May 1;5(5):403-6.
131. Hasasan V, Hossein ZA. Responsiveness of Anopheles maculipennis to different imagicides during resurgent malaria. Asian Pacific Journal of Tropical Medicine. 2010 May 1;3(5):360-3.
132. Manouchehri AV, Zaini A, Javadian E, Saebi E. Resistance of Anopheles sacharovi favor to DDT in Iran. Iranian J of Publ Health 1974; 4: 204-211.
133. Vatandoost H, Abai MR. Irritability of malaria vector, Anopheles sacharovi to different insecticides in a malaria–prone area. Asian Pacific journal of tropical medicine. 2012 Feb 1;5(2):113-6.
134. SALARILAK S, VATANDOUST H, ENTEZAR MM, Ashraf H, Abai MR, Nazari M. Monitoring of insecticide resistance in Anopheles sacharovi (Favre, 1903) in borderline of Iran, Armenia, Naxcivan and Turkey, 2001;31(3-4):96-9.
135. Yaghoobi-Ershadi MR, Namazi J, Piazak N. Bionomics of Anopheles sacharovi in Ardebil province, northwestern Iran during a larval control program. Acta tropica. 2001 Mar 30;78(3):207-15.
136. Saidi S, Tesh R, Javadian E, Nadim A. The prevalence of human infection with West Nile virus in Iran. Iranian Journal of Public Health. 1976:8-13.
137. Mobedi I, Javadian E, Abai MR. Introduction of zoonosis focus of dog heart worm (Dirofilaria immitis, Nematoda: Filarioidea) in Meshkin-Shahr area, East Azerbaijan

province and its public health importacne in Iran. InThe First Congress of Parasitic Diseases in Iran 1990.

138. Lotfi MD, Manouchehri AV, Yazdanpanah H. Resistance of Culex pipiens pipiens to DDT in Northern Iran, 1973. Bulletin de la Société de Pathologie Exotique. 1975;68(1):91-9.

139. Naseri-Karimi N, Vatandoost H, Bagheri M, Chavshin AR. Susceptibility status of Culex pipiens against deltamethrin and DDT, Urmia County, West Azerbaijan Province, northwestern Iran. Asian Pacific Journal of Tropical Disease. 2015 Jan 1;5:S77-9.

140. Salim-Abadi Y, Oshaghi MA, Enayati AA, Abai MR, Vatandoost H, Eshraghian MR, Mirhendi H, Hanafi-Bojd AA, Gorouhi MA, Rafi F. High insecticides resistance in Culex pipiens (Diptera: Culicidae) from Tehran, capital of Iran. Journal of arthropod-borne diseases. 2016 Dec;10(4):483-92.

141. Nazni WA, Lee HL, Azahari AH. Adult and larval insecticide susceptibility status of Culex quinquefasciatus (Say) mosquitoes in Kuala Lumpur Malaysia. Trop Biomed. 2005 Jun;22(1):63-8.

142. Kim NJ, Chang KS, Lee WJ, Ahn YJ. Monitoring of insecticide resistance in field-collected populations of Culex pipiens pallens (Diptera: Culicidae). Journal of Asia-Pacific Entomology. 2007 Sep 1;10(3):257-61.

143. VATANDOUST H, Ezeddinloo L, Mahvi AH, Abai MR, Kia EB, MOUBEDI I. Enhanced tolerance of house mosquito to different insecticides due to agricultural and household pesticides in sewage system of Tehran, Iran. Iranian J Env Health Sci Eng 2004; 1(1): 42-5.

144. Tantely ML, Tortosa P, Alout H, Berticat C, Berthomieu A, Rutee A, Dehecq JS, Makoundou P, Labbé P, Pasteur N, Weill M. Insecticide resistance in Culex pipiens quinquefasciatus and Aedes albopictus mosquitoes from La Reunion Island. Insect Biochemistry and Molecular Biology. 2010 Apr 1;40(4):317-24.

145. Karunaratne SHPP , Hemingway J. Insecticide resistance spectra and resistance mechanisms in populations of japanese encephalitis vector mosquitoes, culex tritaeniorhynchus and cx. gelidus, in sri lanka. Med Vet Entomol 2000; 14: 430-436.

146. Edi CV, Koudou GB, Jones CM, Weetman D, Ranson H. Multiple insecticide resistance in Anopheles gambiae mosquitoes, Southern Côte d'Ivoire. Emerg Infect Dis 2012; 18: 1508–1511.

147. Corbel V, N'guessan R, Brengues C, Chandre F, Djogbenou L, Martin T, Akogbeto M, Hougard JM, Rowland M. Multiple insecticide resistance mechanisms in Anopheles gambiae and Culex quinquefasciatus from Benin, West Africa. Acta tropica. 2007 Mar 1;101(3):207-16.

148. Hardstone MC, Leichter CA, Scott JG. Multiplicative interaction between the two major mechanisms of permethrin resistance, kdr and cytochrome P450-monooxygenase detoxification, in mosquitoes. Journal of evolutionary biology. 2009 Feb;22(2):416-23.

149. Grigoraki L, Balabanidou V, Pipini D, Strati F, Vontas J. Analysis of insecticide resistance in mosquito disease vectors: From molecular mechanisms to management. Nova Acta Leopoldina NF Nr 2016; 411: 165 –171.

150. Enayati AA, Vatandoost H, Ladonni H, Townson H, Hemingway J. Molecular evidence for a kdr-like pyrethroid resistance mechanism in the malaria vector mosquito Anopheles stephensi. Medical and veterinary entomology. 2003 Jun;17(2):138-44.

151. Soderlund DM, Knipple DC. The molecular biology of knockdown resistance to pyrethroid insecticides. Insect biochemistry and molecular biology. 2003 Jun 1;33(6):563-77.

152. Xu Q, Zhang L, Li T, Zhang L, He L, Dong k, Liu N. Evolutionary adaption of the amino acid and codon usage of the mosquito sodium channel following permethrin selection. PLOS ONE 2012; 7(10):e47609.

153. Silva AP, Santos JM, Martins AJ. Mutations in the voltage-gated sodium channel gene of anophelines and their association with resistance to pyrethroids–a review. Parasites & vectors. 2014 Dec;7(1):450.

154. Du Y, Nomura Y, Satar G, Hu Z, Nauen R, He SY, et al. Molecular evidence for dual pyrethroid receptor sites on a mosquito sodi-

um channel. Proc. Natl. Acad. Sci. USA 2013; 110(29):11785–90

155. Jones CM, Liyanapathirana M, Agossa FR, Weetman D, Ranson H, et al. Footprints of positive selection associated with amutation (N1575Y) in the voltage-gated sodium channel of Anopheles gambiae. Proc Natl Acad Sci USA 2012; 109(17): 6614–19.
156. Singh OP, Dykes CL, Das MK, Pradhan S, Bhatt RM, Agrawal OP, Adak T. Presence of two alternative kdr-like mutations, L1014F and L1014S, and a novel mutation, V1010L, in the voltage gated Na+ channel of Anopheles culicifacies from Orissa, India. Malaria journal. 2010 Dec 1;9(1):146.
157. Srisawat R, Komalamisra N, Eshita Y, Zheng M, Ono K, Itoh TQ, Matsumoto A, Petmitr S, Rongsriyam Y. Point mutations in domain II of the voltage-gated sodium channel gene in deltamethrin-resistant Aedes aegypti (Diptera: Culicidae). Applied Entomology and Zoology. 2010 May 25;45(2):275-82.
158. Chang C, Shen WK, Wang TT, Lin YH, Hsu EL, Dai SM. A novel amino acid substitution in a voltage-gated sodium channel is associated with knockdown resistance to permethrin in Aedes aegypti. Insect biochemistry and molecular biology. 2009 Apr 1;39(4):272-8.
159. Kawada H, Oo SZM, Thaung S, Kawashima E, Maung YNM, Thu HM, et al. Co-occurrence of point mutations in the voltage-gated sodium channel of pyrethroid-resistant Aedes aegypti populations in Myanmar. PLOS Negl. Trop Dis 2014; 8(7), e3032 doi:10.1371/journal.pntd.0003032
160. Kheirandish A. Resistances mechanisms of Anophels and Culex mosquites to insecticides: A practical review. Scientific Medical Journal, Ahvaz Jundishapur University of Medical Sciences. 1998;24:30-45.
161. Abuelmaali SA, Elaagip AH, Basheer MA, Frah EA, Ahmed FTA, Elhaj HF, et al. Impacts of agricultural practices on insecticide resistance in the malaria vector Anopheles arabiensis in Khartoum State, Sudan. PLoS One 2013; 8(11): e80549.
162. Davies TGE, Field LM, Usherwood PNR, Williamson MS. A comparative study of voltage-gated sodium channels in the insecta: implications for pyrethroid resistance in Anopheline and other Neopteran species. Insect Mol Biol 2007;16: 361–375.
163. Enayati AA, Ranson H, Hemingway J. Insect glutathione transferases and insecticide resistance. Insect Mol Biol 2005;14 (1): 3–8.
164. MOURYA DT, HEMINGWAY J, LEAKE CJ. Changes in enzyme titres with age in four geographical strains of Aedes aegypti and their association with insecticide resistance. Medical and veterinary entomology. 1993 Jan;7(1):11-6.
165. Amin AM, Hemingway J. Preliminary investigation of the mechanisms of DDT and pyrethroid resistance in Culex quinquefasciatus Say (Diptera: Culicidae) from Saudi Arabia. Bulletin of Entomological Research. 1989 Sep;79(3):361-6.
166. Weill M, Malcolm C, Chandre F, Mogensen K, Berthomieu A, Marquine M, et al. The unique mutation in ace-1 giving high insecticide resistance is easily detectable in mosquito vectors. Insect. Mol. Biol 2004; 13(1): 1–7.
167. Mutero A, Pralavorio M, Bride JM, Fournier D. Resistance-associated point mutations in insecticide-insensitive acetylcholinesterase. Proceedings of the national academy of sciences. 1994 Jun 21;91(13):5922-6.
168. Du W, Awolola TS, Howell P, Koekemoer LL, Brooke BD, Benedict MQ, Coetzee M, Zheng L. Independent mutations in the Rdl locus confer dieldrin resistance to Anopheles gambiae and An. arabiensis. Insect molecular biology. 2005 Apr;14(2):179-83.
169. Cole LM, Nicholson RA, Casida JE. Action of phenylpyrazole insecticides at the GABA-gated chloride channel. Pesticide Biochemistry and Physiology. 1993 May 1;46(1):47-54.
170. ffrench-Constant RH, Anthony N, Aronstein K, Rocheleau T, Stilwell G. Cyclodiene insecticide resistance: from molecular to population genetics. Annual review of entomology. 2000 Jan;45(1):449-66.
171. Hemingway J, Karunaratne SH. Mosquito carboxylesterases: a review of the molecular biology and biochemistry of a major insecticide resistance mechanism. Medical and veterinary entomology. 1998 Jan;12(1):1-2.

172. Scott JG. Cytochromes P450 and insecticide resistance. Insect biochemistry and molecular biology. 1999 Sep 1;29(9):757-77.
173. Gunasekaran K, Muthukumaravel S, Sahu SS, Vijayakumar T, Jambulingam P. Glutathione S transferase activity in Indian vectors of malaria: A defense mechanism against DDT. J Med Entomol 2011; 48: 561–569.
174. Prapanthadara LA, Koottathep S, Promtet N, Hemingway J, Ketterman AJ. Purification and characterization of a major glutathione S-transferase from the mosquito Anopheles dirus (species B). Insect Biochemistry and Molecular Biology. 1996 Mar 1;26(3):277-85.
175. Prapanthadara LA, Hemingway J, Ketterman AJ. Partial purification and characterization of glutathione S-transferases involved in DDT resistance from the mosquito Anopheles gambiae. Pesticide Biochemistry and Physiology. 1993 Oct 1;47(2):119-33.
176. Clark AG, Shamaan NA. Evidence that DDT-dehydrochlorinase from the house fly is a glutathione S-transferase. Pesticide Biochemistry and Physiology. 1984 Dec 1;22(3):249-61.
177. Grant DF, Dietze EC, Hammock BD. Glutathione S transferase isozymes in Aedes aegypti: purification, characterization, and isozyme specific regulation. Insect Biochem 1991; 4: 421–33.
178. Ortelli F, Rossiter LC, Vontas J, Ranson H, Hemingway J. Heterologous expression of four glutathione transferase genes genetically linked to a major insecticide-resistance locus from the malaria vector Anopheles gambiae. Biochemical Journal. 2003 Aug 1;373(3):957-63.
179. Hayes JD, Wolf CR. Role of glutathione transferase in drug resistance. In Glutathione Conjugation: Mechanisms and Biological Significance (Sies, H. and Ketterer, B., eds), pp. 315–355. Academic Press Ltd, London.
180. Kasai S, Komagata O, Itokawa K, Shono T, Ng L, Kobayashi M, et al. Mechanisms of pyrethroid resistance in the dengue mosquito vector, Aedes aegypti: target site insensitivity, penetration, and metabolism. PLOS Negl Trop Dis 2014; 8(6): e2948.
181. Stevenson BJ, Pignatelli P, Nikou D, Paine MJ. Pinpointing P450s associated with pyrethroid metabolism in the dengue vector, Aedes aegypti: developing new tools to combat insecticide resistance. PLOS Negl Trop Dis 2012; 6(3), e1595.
182. Stevenson BJ, Bibby J, Pignatelli P, Muangnoicharoen S, O'Neill PM, Lian LY, et al. Cytochrome P450 6M2 from the malaria vector Anopheles gambiae metabolizes pyrethroids: Sequential metabolism of deltamethrin revealed. Insect Biochem Mol Biol 2011; 41: 492–502.
183. Mitchell SN, Stevenson BJ, Müller P, Wilding CS, Egyir-Yawson A, Field SG, Hemingway J, Paine MJ, Ranson H, Donnelly MJ. Identification and validation of a gene causing cross-resistance between insecticide classes in Anopheles gambiae from Ghana. Proceedings of the National Academy of Sciences. 2012 Apr 17;109(16):6147-52.
184. Muller P, Warr E, Stevenson BJ, Pignatelli PM, Morgan JC, Steven A, et al. Field-caught permethrin-resistant Anopheles gambiae overexpress CYP6P3, a P450 that metabolises pyrethroids. PLOS Genet 2008; 4(11): e1000286.
185. Edi CV, Djogbenou L, Jenkins AM, Regna K, Muskavitch MA, Poupardin R, et al. CYP6 P450 enzymes and ACE-1 duplication produce extreme and multiple insecticide resistance in the malaria mosquito Anopheles gambiae. PLOS Genet 2014;10(3): e1004236.
186. Kumar SA, Pillai TMK. Involvement of mono-oxygenases as a major mechanism of deltamethrin resistance in larvae of three species of mosquitoes. Indian J Exp Biol 1991; 29:379-84.
187. Enayati AA, Ladonni H. Biochemical assay baseline data of permetrhin resistance in Anopheles stephensi (Diptera, Culicidae)from Iran. Pakistan J Biolo Sci, 2006; 9(7):1265-1270.
188. Hemingway J. Biochemical studies on malathion resistance in Anopheles arabiensis from Sudan. Transactions of the Royal Society of Tropical Medicine and Hygiene, 1983;77(4): 477-480.
189. Hemingway J, Hawkes NJ, McCarroll L, Ranson H. The molecular basis of insecticide resistance in mosquitoes. Insect biochemistry and molecular biology. 2004 Jul 1;34(7):653-65.

190. Nasirian H. An overview of German cockroach, Blattella germanica, studies conducted in Iran. Pakistan Journal of biological sciences. 2010 Nov 15;13(22):1077-84.
191. Wang C, Bennett GW. Comparative study of integrated pest management and baiting for German cockroach management in public housing. J Econ Entomol 2006; 99: 879–885.
192. Lee CY, Yap HH, Chong NL. Insecticide resistance and synergism in field collected German cockroaches (Dictyoptera: Blattellidae) in Peninsular Malaysia. Bull Entomol Res 1996; 86: 675–682.
193. Whalon ME, Mota-Sanchez RM, Hollingworth RM. Arthropods resistant to pesticides database (ARPD).Available online: http://www.pesticideresistance.org
194. Cochran DG, Ross MH. Inheritance of DDT-Resistance in a European Strain of Blattella germanica (L.). Bull Org mond Sante 1962; 27:257-261.
195. Clarke TH, Cochran DG. Cross-resistance in insecticide-resistant strains of the German cockroach, Blattella germanica (l.) Bull Wld Hlth Org 1959; 20: 823-833.
196. Lee CY, Lee LC, Ang BH, Chong NL. Insecticide Resistance in Blattella germanica (L.) (Dictyoptera: Blattellidae) from Hotels and Restaurants in Malaysia. Proceedings of the 3rd International Conference on Urban Pests. 1999; 171-181.
197. Chang KS, Shin EH, Jung JS, Park C, Ahn YJ. Monitoring for insecticide resistance in field-collected populations of Blattella germanica (Blattaria: Blattellidae) J Asia Pac Entomol 2010; 13: 309–312.
198. Chai RY, Lee CY. Insecticide resistance profiles and synergism in field populations of the German cockroach (Dictyoptera: Blattellidae) from Singapore. J Econ Entomol 2010;103: 460–471.
199. Rust MK, Reierson DA, Zeichner BC. Relationship between insecticide resistance and performance in choice tests of field-collected German cockroaches (Dictyoptera: Blattellidae). J Econ Entomol 1993; 86: 1124-1130.
200. Hemingway J, Small GJ. Resistance mechanisms in cockroaches: the key to control strategies. Proceed 1st Intl Conf Urban Pests. Wildey KB, Robinson WmH (editors). 1993; 141-152.
201. Qian K, Wei XQ, Zeng XP, Liu T, Gao XW. Stage-dependence tolerance of the German cockroach, Blattella germanica, for dichlorovos and propoxur. J Insect Sci 2010; 10: 201-210.
202. Rahayu R, Madona WR, Bestari W, Dahelmi , Jannatan J. Resistance monitoring of some commercial insecticides to German cockroach (Blattella germanica (L.) in Indonesia. J Entomol Zool Stud 2016; 4(6): 709-712.
203. Anspaugh DD, Rose RL, Koehler PG, Hodgson E, Roe RM. Multiple mechanisms of pyrethroid resistance in the German cockroach, Blattella germanica (L.). Pesticide Biochemistry and Physiology. 1994 Oct 1;50(2):138-48.
204. Wu D, Scharf ME, Neal JJ, Suiter DR, Bennett GW. Mechanisms of fenvalerate resistance in the German cockroach, Blattella germanica (L.). Pest Biochem Physiol 1998; 61:53-62.
205. Valles SM, Dong K, Brenner R. Mechanisms responsible for cypermethrin resistance in a strain of German cockroach, Blattella germanica. Pest Biochemi Physiol 2000; 66:195-205.
206. Limoee M, Enayati AA, Ladonni H, Vatandoost H, Baseri H, Oshaghi MA. Various mechanisms responsible for permethrin metabolic resistance in seven field-collected strains of the German cockroach from Iran, Blattella germanica (L.) (Dictyoptera: Blattellidae). Pestic Biochem Physiol 2007; 87: 138–146.
207. Limoee M, Ladonni H, Enayati AA, Vatandoost H, Aboulhasni M. Detection of pyrethroid resistance and cross-resitance to DDT in seven field-collected strains of the German cockroach Blattella germanica (L.)(Dictyoptera:Blattellidae). J Biol Sci 2006; 6:382-387.
208. Ladonni H, Shaeghi M, Shahgholian-Ghahfarrokhi A. Permethrin resistance compaired glass petri- dish and insecticide-impregnated paper methods for first instar of German cockroach (Dict.:Blattellidae). J Entomol Society of Iran 2001; 20:23-31.
209. Limoee M, Shayeghi M, Heidary J, Nassirian H, Ladonni H. Susceptibility of different

hospital collected strains of German cockroaches Blattella germanica (L.) (Dictyoptera: Blattellidae) to different classes of insecticide, carbamates and organophosphorous. Behbood, Journal of KUMS 2010; 13:337-343.

210. Camyabi F, Vatandoost H, Aboulhassani M, Aghasi M, Telmadarei Z, Abaei M. Susceptibility of German cockroach to three insecticides premiphos methyl, lambda cyhalothrin and propoxur in three hospitals in Kerman. Journal of Mazandaran University of Medical Sciences. 2006;16:98-108.

211. Ladonni H. Susceptibility of Blattella germanica to different insecticides in different hospitals in Tehran-Iran. Journal of Entomology Society of Iran 1993; 12-13: 23-28.

212. Limoee M, Enayati AA, Khassi K, Salimi M, Ladonni H. Insecticide resistance and synergism of three field-collected strains of the German cockroach Blattella germanica (L.)(Dictyoptera: Blattellidae) from hospitals in Kermanshah, Iran. Trop Biomed. 2011 Apr 1;28(1):111-8.

213. Limoee M, Davari B, Moosa-Kazemi SH. Toxicity of pyrethroid and organophosphorous insecticides against two field collected strains of the German cockroach Blattella germanica (Blattaria: Blattellidae). Journal of Arthropod Borne Diseases 2012; 6(2): 112-8.

214. Moemenbellah-Fard MD, Fakoorziba MR, Azizi1 K, Mohebbi-Nodezh M. Carbamate Insecticides Resistance Monitoring of Adult Male German Cockroaches, Blattella germanica (L.), in Southern Iran. J Health Sci Surveillance Sys 2013;1(1): 41-7.

215. Salehi A, Vatandoost H, Hazratian T, Sanei-Dehkordi A, Hooshyar H, Arbabi M, et al. Detection of Bendiocarb and Carbaryl Resistance Mechanisms among German Cockroach Blattella germanica (Blattaria: Blattellidae) Collected from Tabriz Hospitals, East Azerbaijan Province, Iran in 2013. J Arthropod-Borne Dis 2016; 10(3):403–12.

216. Ladonni H. SUSCEPTIBILITY OF DIFFERENT FIELD STRAINS OF BLATTELLA GERMANICA TO FOUR PYRETHROIDES (ORTHOPTERA: BLATTELLIDEA). Iranian Journal of Public Health. 1997:35-40.

217. Gholizadeh S, Nouroozi B, Ladonni H. Molecular detection of knockdown resistance (kdr) in Blattella germanica (Blattodea: Blattellidae) from northwestern Iran. J Med Entomol 2014; 51(5):976-9.

218. Enayati AA, Motevalli Haghi F. Biochemistry of pyrethroid resistance in German Cockroach (Dictyoptera, Blatellidae) from hospitals of Sari, Iran. Iranian Biomed J 2007; 11 (4): 251-8.

219. Doroudgar A, Paksa A, Vatandoost H, Sanei-Dehkordi A, Salim-Abadi Y. Detection of cyfluthrin resistance mechanisms among German cockroach strains in vivo in Kashan during 2011-2012. Feyz, Journal of Kashan University of Medical Sciences 2014; 17(6), 590-6.

220. Nasirian H, Ladonni H, Shayeghi M, Vatandoost H, Yaghoobi-Ershadi MR, Rassi Y, et al. Comparison of Permethrin and Fipronil Toxicity against German Cockroach (Dictyoptera: Blattellidae) Strains. Iranian J Publ Health 2006; 35(1);63-7.

221. Nasirian H, Ladonni H, Aboulhassani M, Limoee M. Susceptibility of field populations of Blattella germanica (Blattaria: Blattellidae) to spinosad. Pakistan J Biolo Sci 2011;14(18): 828-62.

222. Liu Z, Valles SM, Dong K. Novel point mutations in the German cockroach para sodium channel gene are associated with knockdown resistance (kdr) to pyrethroid insecticides. Insect biochemistry and molecular biology. 2000 Oct 1;30(10):991-7.

223. Bennett GW. Examination of esterases from insecticide resistant and susceptible strains of the German cockroach, Blattella germanica (L.). Insect Biochem Mol Biol 1997; 27(6): 489-97.

224. Scharf ME, Neal JJ, Bennett GW. Changes of insecticide resistance levels and detoxication enzymes following insecticide selection in the German cockroach, Blattella germanica (L.). Pest Bioche. Physio 1997; 59: 67-79.

225. Hemingway J, Small GJ, Monro AG, Possible mechanisms of organophosphorus and carbamate insecticide resistance in German cockroaches (Dictyoptera: Blattelidae) from different geographical areas. J Econ Entomol 1993; 86:1623–30.

226. Pridgeon JW, Zhang L, Liu N. Overexpression of CYP4G19 associated with a py-

rethroid-resistant strain of the German cockroach, Blattella germanica (L.). Gene 2003; 314:157–63.

227. Valles SM, Koehler PG, Brenner RJ. Antagonism of fipronil toxicity by piperonyl butoxide and S, S, S-tributyl phosphorotrithioate in the German cockroach (Dictyoptera: Blattellidae). J Econ Entomol 1997; 90:1254–8
228. Gondhalekar AD, Scharf ME. Mechanisms underlying fipronil resistance in a multiresistant field strain of the German cockroach (Blattodea: Blattellidae). J Med Entomol 2012; 49:122–31.
229. Danxia WU, Scharf ME, Neal JJ, Suiter DR and Bennett GW. Mechanisms of Fenvalerate resistance in the German Cockroach, Blattella germanica (L.) Pesticide Biochemistry and Physiology 1998; 61, 53–62.
230. Dehghani R, Khoobdel M, Sobati H. Scorpion Control in Military Units: A Review Study. J Mil Med. 2018; 20 (1):3-13.
231. Santibáñez-López CE, Francke OF, Ureta C, Possani LD. Scorpions from Mexico: From species diversity to venom complexity. Toxins 2016; 8(2):2.
232. .Dehghani R, Khamehchian T, Miranzadeh MB. Surveying on the Biologic behaviors of Hemiscorpius lepturus (Peters, 1861) scorpion in laboratory (Khuzestan, Iran) (Scorpions: Hemiscorpiidae), Pakestan Journal of Biological Sciences 2007;10(18): 3097-3102.
233. Dehghani R, Arani MG, Scorpion sting prevention and treatment in ancient Iran, J Traditional and Complementary Med 2015; 5(2): 75 - 80.
234. Dehghani R, Kamiabi F, Mohammadi M, Scorpionism by Hemiscorpius spp. in Iran: a review. J Venom Anim Toxins Incl Trop Dis 2018; 24:8.
235. Dehghani R, Rafinejad J, Fathi B, Panjeh-Shahi M, Jazayeri M, Hashemi A. A Retrospective Study on Scropionism in Iran (2002–2011). J Arthropod-Borne Dis 2017;11(2):184-93.
236. Ahmadimarzale M, Sabuhi H, Sabahi Bidgoli M, Dehghani R, Hoseindoost G, Mesgari L. Study of scorpion species abundance in cities Aran & Bidgol and Kashan, Isfahan, Iran. J. ent. Res 2017; 41 (3): 337-42.
237. Shahbazzadeh D, Amirkhani A, Djadid ND, Bigdeli S, Akbari A, Ahari H, et al. Epidemiological and clinical survey of scorpionism in Khuzestan province, Iran (2003). Toxicon 2009; 53(4): 454-9.
238. Sanaei-Zadeh H, Marashi SM, Dehghani R. Epidemiological and clinical characteristics of scorpionism in Shiraz (2012-2016); development of a clinical severity grading for Iranian scorpion envenomation. Medical journal of the Islamic Republic of Iran. 2017;31:27.
239. .Yousef Mogaddam M, Dehghani R, Enayati AA, Fazeli-Dinan M, Motevalli Haghi F. Epidemiology of scorpionism in Darmian, Iran, 2015. J Mazandaran Univ Med Sci 2016; 26 (141):131-6.
240. Dehghani R, Vazirianzadeh B, Rahimi Nasrabadi M, Moravej SA. Study of scorpionism in Kashan in central Iran. Pak J Med Sci 2010; 26(4): 955-8.
241. Yousef Mogaddam M, Dehghani R, Enayati AA, Fazeli-Dinan M, Vazirianzadeh B, Yazdani-Cherati J et al . Scorpion Fauna (Arachnida: Scorpiones) in Darmian County, Iran (2015-2016). J Mazandaran Univ Med Sci. 2017; 26 (144):108-18.
242. Zargan J, Tahernejad K, Mehrabitavana A, Farahmandzad AR, Subati H. Study of sensitivity levels in six species of Iranian scorpions against chemical pesticides. Kowsar Med J 2002; 6 (4):233-9.
243. Dehghani R, Valizade R, Mahmoodi S .A review of the scorpion predators and the introduction of Scarites subterraneus, as a new predatory of them in Iran. J ent Res 2016; 40 (3): 291-96.
244. Dehghani R. Solpugidophobia in Iran: Real or Illusion. J Biol Today's World 2017; 6 (3):46-8.
245. Robinson WH. Integrated pest management in the urban environment. American Entomologist. 1996 Apr 1;42(2):76-8.
246. Ranson H, N'Guessan R, Lines J, Moiroux N, Nkuni Z, Corbel V. Pyrethroid resistancein African anopheline mosquitoes: what are the implications for malaria control? Trends in Parasitol 2011; 27(2): 988-91.
247. Greene A, Breisch NL. Measuring integrated pest management programs for public buildings. J Econ Entomol 2002; 95:1-13.

248. Williams GM, Linker HM, Waldvogel MG, Leidy RB, Schal C. Comparison of conventional and integrated pest management programs in public schools. J Econ Entomol 2005; 98: 1275-83.
249. Granovsky TA. Stored product pests, pp. 634-729. In A. Mallis (eds.). Handbook of Pest Control: The Behavior, Life History, and Control of Household Pests. Mallis Handbook and Technical Training Company.
250. Chandler D, Bailey AS, Tatchell GM, Davidson G, Greaves J, Grant WP. The development, regulation and use of biopesticides for integrated pest management. Philos Trans R Soc Lond B 2011; 366: 1987–98.
251. WHO. Global Plan for Insecticide Resistance Management in Malaria Vectors (GPIRM); WHO: Geneva, Switzerland, 2012.
252. IRAC. Prevention and management of insecticide resistance in vectors and pests of public health importance. A manual produced by Insecticide Resistance Action Committee (IRAC).
253. Alphey L. Genetic control of mosquitoes. Annu Rev Entomol 2014; 59: 205–24.
254. Knipling EF. Possibilities of insect control or eradication through the use of sexually sterile males. J Econ Entomol 1955; 48: 459–62.
255. Krafsur ES. Sterile insect technique for suppressing and eradicating insect population: 55 years and counting. J Agric Entomol 1998; 15: 303–317.
256. Lacroix R, McKemey AR, Raduan N, Wee LK, Ming WH, Ney TG, et al. Open field release of genetically engineered sterile male Aedes aegypti in Malaysia. PLoS ONE 2012; 7(8): e42771.
257. Burt A. Heritable strategies for controlling insect vectors of disease. Philos. Trans R Soc B Biol Sci 2014; 369 (1645): 2013.0432
258. Thomas DD, Donnelly CA, Wood RJ, Alphey LS. Insect population control using a Dominant, Repressible, Lethal Genetic System. Science 2000:287(5462): 2474-6.
259. McGraw EA, O'Neill SL. Beyond insecticides: New thinking on an ancient problem. Nat Rev Microbiol 2013; 11:181–193.
260. Windbichler N, Menichelli M, Papathanos PA, Thyme SB, Li H, Ulge UY, et al. A synthetic homing endonuclease-based gene drive system in the human malaria mosquito. Nature 2011; 473:212–15.
261. Regnault-Roger C. Botanicals in pest management. In Integrated Pest Management; Abrol, D.P., Shankar, U., Eds.; CAB International: Oxfordshire, UK, 2012; 119–32.
262. Rizvi PQ, Ahmad SK, Choudhury RA, Ali A. Biopesticides in ecologically-based integrated pest management. In Integrated Pest Management; Abrol, D.P., Shankar, U., Eds.; CAB International: Oxfordshire, UK, 2012; pp. 133–61.
263. Bielza P, Quinto V, Contreras J, Torne, M, Martın A, Espinosa PJ. Resistance to spinosad in the western flower thrips, Frankliniella occidentalis (Pergande), in greenhouses of south-eastern Spain. Pest Manag Sci 2007; 63: 682–87.
264. Sato M E, Da Silva MZ, Raga A, De Souza MF. Abamectin resistance in Tetranychus urticae Koch (Acari: Tetranychidae): selection, cross-resistance and stability of resistance. Neotrop Entomol 2005; 34: 991–98.
265. Regnault-Roger C, Vincent C, Arnason, JT. Essential oils in insect control: Low-risk products in a high-stakes world. Annu Rev Entomol 2012; 57: 405–24.
266. Zoubiri S, Baaliouamer A. Potentiality of plants as source of insecticide principles. Journal of Saudi Chemical Society 2014; 18: 925–38.