

Control of Cockroaches (Blattaria) in Sewers: A Practical Approach Systematic Review

Hassan Nasirian^{1,3,*} and Aref Salehzadeh²

¹Department of Medical Entomology and Vector Control, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran, ²Department of Medical Entomology, School of Medicine, Hamadan University of Medical Sciences, Hamadan, Iran, and

³Corresponding author, e-mail: hanasirian@yahoo.com

Subject Editor: Richard Johnson

Received 12 August 2018; Editorial decision 20 October 2018

Abstract

Periplaneta americana (L.) (Blattaria: Blattidae), the American cockroach, is the most important invasive urban pest of sewer environments colonizing there with high significance of human public health and household allergens need to be controlled. Therefore this practical approach systematic review perform internationally to highlight and provide a detailed *P. americana* control in sewers. Among 474 searched papers, 129 of those were selected to become this practical approach systematic review of the American cockroach control in sewers. To control the American cockroaches, many studies have been conducted in various fields describing from an angle. The results were classified and discussed in getting cockroaches from sewers into buildings and their elimination, insecticide susceptibility, application of dust, bait and Inesfly paint insecticide formulations, biocontrol, and futuristic action categories. A recommending manner to achieve a successful *P. americana* cockroach control in sewers is using a combination of Integrated Pest Management (IPM) strategies resulted in significant reductions of cockroach infestations and asthma health outcomes. Use of the American cockroach breeding thelytoky, push–pull strategies and an automated sewer robot, and integrating health into the future buildings may be new approaches of the American cockroach control strategies.

Key words: American cockroach, *Periplaneta americana*, allergen, integrated pest management, IPM

Cockroaches (Blattaria) have a world-wide distribution especially in the tropical and subtropical areas. They demonstrate extraordinary adaptation to a wide range of habitats, reproduce rapidly, and have filthy habits and a bad smell. Cockroaches have been proved acting as probable carriers of the pathogenic or opportunistic bacteria and fungi found in nosocomial infections, and food-borne poisoning mostly being drug resistant. They involve in human intestinal parasites and intermediate hosts, and play a role as a major source of allergens (Tachbele et al. 2006; Salehzadeh et al. 2007; Fakoorziba et al. 2010; Kassiri and Kazemi 2012; Page 2012; Pai 2013; Motevali Haghi et al. 2014a,b; Menasria et al. 2015; Varadinová et al. 2015; Nasirian 2016; Atiokeng Tatang et al. 2017; Davari et al. 2017a; Martínez-Girón et al. 2017; Nasirian 2017a,b; Esty and Phipatanakul 2018; Nasirian 2018; Schapheer et al. 2018; Sookrung et al. 2018). In addition to the great medical importance, cockroaches are a common and important pest that inhabit various public places (Wagan et al. 2017) and are one of the key group of insect pests in sewer environments (Gul et al. 2017).

After developing and increasing the population of the cities and expanding of industries and factories, the issue of environmental

pollution is becoming increasingly important. Effective collection and treatment of urban waste water is essential to the health of our rivers, lakes and coastal waters and to protect human health. The collection of sanitary and human wastewaters is one of the most important issues of urban and rural life due to the high levels of contamination and pathogenic microorganisms toxicity and odor nuisance to the network stakeholders and the public (Carrera et al. 2016, EPA 2016, Shammay et al. 2016). So at first the wastewaters need to be decontaminated, and then returned into the flow of water in the nature after their collecting and bringing out of the towns by sewers.

The most common worldwide cockroaches are the American (*Periplaneta americana*), the German (*Blattella germanica*), the Oriental (*Blatta orientalis*), and the brown-banded (*Supella longipalpa*) cockroaches (Sulaiman et al. 2011, Nasirian 2016). *Periplaneta americana* (L.) (Blattaria: Blattidae) is one of the most important synanthropic invasive and hygienic urban pests distributed worldwide. This pest species is an annoyance to human as associates with diseases and allergies, and damages to clothes and documents (Hwang and Chen 2004, Reiersen et al. 2005, Baggio-Deibler et al.

2018, Zhu et al. 2018). The American cockroaches are also a prevailing species and important sources of household allergens (Hubner-Campos et al. 2013, Carlson et al. 2017, Esty and Phipatanakul 2018, Sookrung et al. 2018). Unlike the German cockroach being the most invading pests of human dwellings (Noureldin and Farrag 2008, Paksa et al. 2012, Nazari et al. 2016, Tang et al. 2016, Sanei Dehkordi et al. 2017, Davari et al. 2018, Nasirian 2018), it is considerable that *P. americana* species is the most important pests of sewers. The appropriate conditions of the sewers such as humidity, temperature, darkness of the environment, and presence of plenty of water and food have made sewers as a suitable environment to the growth and reproduction of the American cockroaches. In fact, a sewer is a perfect home for the American cockroaches. An underground sewer system is insulated, warm in winter, and cool in summer. A sewer provides protection from people and predators with the possible exception of hungry rats. The substantial problem is when these creatures exit the sewers and enter the people homes and other buildings. A large-scale of *P. americana* cockroaches migrates to human dwellings via breathing manholes of sewers.

Nowadays, *P. americana* not only is a domiciliary pest but also the most frequent species in sewers which colonize there turning into suitable environment for reproduction and growth with high significance of human public health throughout the world, especially in metropolitan areas neglecting maintenance of manholes for long periods. They frequently invade surrounding buildings after moving from sewers (Reierson et al. 2005, Tee et al. 2011b, Bueno-Marí et al. 2013, Dehghani et al. 2014, Lupo 2017, Alias and Retnani 2018). When cockroaches are occupying sewers and, more importantly, escaping from sewers, solving the problem is not as easy as we would think required control measures. Treating the sewers with insecticides can become a political and regulatory issue, involving coordination with the sewer authority. The older the sewers, the more likely it is to be infested with cockroaches, and the more difficult it will be to solve the problem (Williams 2016).

To control *P. americana*, many studies have been conducted in various fields which has been published in separate papers or notes and describe from an angle of the topic such as getting cockroaches from sewers into buildings and their elimination, sewer cockroach population size and age-class structure, fighting measures such as insecticide susceptibility, application of dust, bait and Inesfly paint insecticide formulations, possible plant essential oil application and biocontrol, and futuristic actions such as integrating health into the future buildings and future techniques for control of cockroaches. Each of them can be a good lever for *P. americana* control measures. Putting the all levers of control on the table in order to use the best optimized *P. americana* control that encountered conditions require to be used. Therefore this practical approach systematic review perform internationally to highlight and provide a detailed of the cockroach control in sewers between July 2017 and July 2018.

Materials and Methods

Paper Collection and Selection for Review

At the first step, some special phrases or key words like 'sewers', 'cockroaches', 'medical importance of cockroaches', '*Periplaneta americana*', 'American cockroach', 'medical importance of *Periplaneta americana*', 'insecticide susceptibility', and 'control of *P. americana* or American cockroaches in sewers' were used to search the relevant papers or notes from websites like Scopus, PubMed, Web of Science, Google Scholar, Springer, Elsevier, ScienceDirect and academic assemblies between July 2017 and July 2018. In the second step, some special phrases or key words were selected among the content

of the searched papers after carefully reading. Then they were used as new key words or phrases to seek the new papers about the subject of the study. Of the 474 papers from the above-mentioned websites, 129 papers were selected to become this practical approach systematic review study of sewer cockroach control.

Paper Data Extraction and Classification

The papers were dedicated to having sewer cockroach control were read carefully and their contents were extracted and categorized using Nasirian (2017a,b; 2018) methodology (Nasirian 2017a,b, Nasirian 2018). Results of cockroach control in sewers which were extracted and classified in separate distinct categories, and their extensive description represented in the section of the results summarized in Table 1.

Results and Discussion

Getting Cockroaches From Sewers Into Buildings and Their Elimination

Having cockroaches in a sewer system would not be a problem, if cockroaches stayed put. But they do not stay put. The American cockroaches have only one generation per year. Adults and nymphs of the American cockroaches are active throughout a year (Tee et al. 2011b). Adults and fully-grown cockroach nymphs migrate from sewers into buildings for food, shelter and overwintering (Williams 2016). The movements of cockroach density rates between the manholes of sewers also correlate with the mean daily minimum temperature (Tee et al. 2011b).

An effective tactic to reduce cockroach allergen exposures is eliminating the cockroaches (Sever et al. 2007). As cockroaches affiliate with food, water, and shelter sources. Therefore potential cockroach food, water, and shelter sources should be eliminated as well as elimination and closing of crevices or cracks (Orkin 2018). To eliminate the cockroaches' water sources and entering points, any cracks or holes in the drain pipes would be located by using a flashlight and would be sealed with appropriate caulk. Standing water attracts cockroaches; so any leaky faucets would be fixed. Crevices and holes around the drain pipes would be sealed with caulk, plaster or cement. Any gaps around the pipes would be looked for and filled with silicone sealant or urethane foam. Any space around the pipes and holes in the walls where they come through the walls would be sealed by using expanding insulation foam (TICLP 2017). After that, a very thorough inspection of the areas should be inspected. Evaluating the situation and making a customized highly effective treatment plan will correlate with the needs (Orkin 2018). Exterior treatments, drain cleaning and treatments, drain traps, and interior inspections are steps of the solutions to eliminate the cockroaches represented briefly by Lupo (2017) that depending on the circumstances need to be accurately implemented (Lupo 2017).

Fighting Measures

Many researches to achieve appropriate and effective insecticides control against cockroaches using newer methods are still ongoing (Buczowski et al. 2001). Various registered aqueous sprays, dusts, and baits are applied to sewer shafts for the American cockroach control (Rust et al. 1991, Reierson et al. 2005). The use of spraying insecticides, and fire and fogging is the most popular method in sewers. Due to the high population density of *P. americana* cockroach species in sewers as a result of suitable warm and humid environment, the choice of an appropriate and effective insecticide is necessary for its control. Resistance of cockroaches to insecticides also can

Table 1. Results of category data extracted and classified about cockroach control in sewers

Category	References
Getting cockroaches from sewers into buildings and their elimination	Tee et al. 2011b, Williams 2016, Lupo 2017, TICLP 2017, Orkin 2018
Insecticide susceptibility	
Resistance of <i>P. americana</i> to cyclodiene	Thompson et al. 1993
Susceptibility of <i>P. americana</i> to lambda-cyhalothrin, permethrin, deltamethrin, cyfluthrin and alpha-cypermethrin	Vythilingam and Sutivigit 1994
Susceptibility of <i>P. americana</i> and <i>B. germanica</i> to commercially dish-washing liquids and cleaners	Baldwin and Koehler 2007
Resistance of <i>P. americana</i> to imidacloprid, deltamethrin, fipronil and <i>Metarhizium anisopliae</i>	Syed et al. 2014
Resistance of <i>P. americana</i> to malathion	Tahir et al. 2017
Effectivity of long-lasting insecticide-treated nets against non-target household insects including <i>P. americana</i>	Sharma et al. 2006
Application of dust formulations	Schofield and Crisafulli 1980, Rust et al. 1991, Reiersen et al. 2005
Application of bait formulations	
Application of abamectin bait against <i>P. americana</i>	Koehler et al. 1991
Application of neonicotinyl baits (fipronil 0.05% and imidacloprid 2.15% gel baits) against <i>P. americana</i>	Reiersen et al. 2005
Application of dust consisting of pyrethrins, piperonyl butoxide, boric acid, and diatomaceous earth against <i>P. americana</i>	Reiersen et al. 2005
Application of bait formulation containing abamectin B ₁ , orthoboric acid, or propoxur against <i>P. americana</i>	Appel et al. 2005
Application of fipronil 0.03% (Goliath gel) against <i>P. americana</i>	Srinivasan et al. 2005
Application of gel baits (0.01 and 0.05% fipronil, and 0.6% indoxacarb) against <i>P. americana</i>	Bayer et al. 2012
Application of indoxacarb 0.6% gel bait (Advion) against <i>P. americana</i>	Anikwe et al. 2014
Application of Potassium alum against <i>P. americana</i>	Salama 2015
Application of <i>Beauveria bassiana</i> bait formulation against <i>P. americana</i>	Wang et al. 2016
Bait preference of <i>P. americana</i> to insecticides and natural foods	Porusia et al. 2017
Application of insecticidal bait to reduce asthma of cockroach exposure	Rabito et al. 2017
Application of Inesfly paint insecticide formulations	Delacour-Estrella et al. 2014, Hazra 2018
Application of plant essential oils as insect repellents	
Repellency of N,N-diethylphenylacetamide (DEPA) against <i>P. americana</i>	Prakash et al. 1990
Application of essential oil of <i>Alpinia calcarata</i> against <i>P. americana</i>	Paranagama and Sujantha Ekanayake 2004
Fumigant effects of <i>Allium sativum</i> , <i>Allium cepa</i> , <i>Thymus vulgaris</i> , <i>Origanum dubium</i> , <i>Rosemarinus officinalis</i> and <i>Brassica nigra</i> against <i>P. americana</i>	Yilmaz and Tunaz 2013
Biocontrol	
Releasing of <i>Aprostocetus hagenowii</i> parasitoid against <i>P. americana</i>	Reiersen et al. 2005
Investigating parasitism of <i>P. americana</i> oothecae by <i>Evania appendigaster</i>	Fox and Bressan-Nascimento 2006
Investigating parasitism of <i>Steinernema carpocapsae</i> nematodes against <i>P. americana</i> and <i>B. germanica</i>	Maketon et al. 2010
Release of <i>Aprostocetus hagenowii</i> parasitoids against <i>P. americana</i>	Tee et al. 2011a
Evaluating of <i>Metarhizium anisopliae</i> , <i>M. robertsii</i> and <i>Beauveria bassiana</i> against <i>P. americana</i>	Hubner-Campos et al. 2013
Evaluating of <i>B. bassiana</i> and <i>M. anisopliae</i> conidial suspensions against <i>P. americana</i>	Hernández-Ramírez et al. 2007
Evaluating of <i>M. anisopliae</i> IP ₄₆ strain against <i>P. americana</i>	Gutierrez et al. 2016
Evaluating of <i>M. anisopliae</i> (the JAB ₆₈ isolate) and <i>B. bassiana</i> (the IBCB ₃₅ isolate) against <i>P. americana</i>	Baggio-Deibler et al. 2018
The challenges of finding environmentally safe treatments	Hwang and Chen 2004, Reiersen et al. 2005, Hernández-Ramírez et al. 2007, Maketon et al. 2010, Kumar Reddy and Lee 2012, Amin et al. 2014, Angelakis and Snyder 2015, Rani et al. 2017, Davari et al. 2018, Orkin 2018
Futuristic actions	
Integrating health into the future buildings	Heidari et al. 2017
Future techniques for control of cockroaches	
The parthenogenesis of domiciliary <i>P. americana</i> cockroaches	Katoh et al. 2017
<i>P. americana</i> exhibits automixis-type thelytoky	Tanaka and Daimon 2018
An automated sewer robot conduct any inspection of the sewage pipeline	Mongeau et al. 2014, Vaani et al. 2017
The use of push-pull strategies in IPM	Cook et al. 2007

be delayed or avoided by using an appropriate insecticide (Tee et al. 2011b, Bueno-Marí et al. 2013).

Insecticide susceptibility (Thompson et al. 1993, Vythilingam and Sutivigit 1994, Baldwin and Koehler 2007, Syed et al. 2014, Tahir et al. 2017), effectivity of long-lasting insecticide-treated nets (LLINs) (Sharma et al. 2006), application of dust, bait and Inesfly paint insecticide formulations (Schofield and Crisafulli 1980, Koehler et al. 1991, Rust et al. 1991, Appel et al. 2005, Reiersen et al. 2005, Srinivasan et al. 2005, Bayer et al. 2012, Anikwe et al. 2014, Delacour-Estrella et al. 2014, Salama 2015, Wang et al. 2016, Porusia et al. 2017, Rabito et al. 2017, Hazra 2018) and plant essential oils as insect repellents (Prakash et al. 1990, Paranagama and Sujantha Ekanayake 2004, Yilmaz and Tunaz 2013), and biocontrol (Reiersen et al. 2005, Fox and Bressan-Nascimento 2006, Hernández-Ramírez et al. 2007, Maketon et al. 2010, Tee et al. 2011a, Hubner-Campos et al. 2013, Gutierrez et al. 2016, Baggio-Deibler et al. 2018) are fighting measures that their extensive description represented and discussed in the following items (Table 1).

Insecticide Susceptibility

Unlike the German cockroaches which its insecticide susceptibility or resistance has been well studied, a few studies have been performed in the field of insecticide susceptibility or resistance against the American cockroaches. There are few studies being also available about the efficacy of insecticide formulations against *P. americana* in sewers (Tee et al. 2011b, Bueno-Marí et al. 2013). Vythilingam and Sutivigit (1994) reported that *P. americana* was susceptible to namely, lambda-cyhalothrin, permethrin, deltamethrin, cyfluthrin, and alpha-cypermethrin pyrethroids. The susceptibility level based on LC_{50} were observed as the lambda-cyhalothrin > permethrin > deltamethrin > cyfluthrin > alpha-cypermethrin order. Lambda-cyhalothrin was the most effective and alpha-cypermethrin was the least effective against *P. americana* (Vythilingam and Sutivigit 1994). However, a study exhibited a moderate levels of resistance (2.0-fold) to deltamethrin against *P. americana* (Syed et al. 2014). Excluding bed bugs, 100% mortality was detected in nontarget household insects including the American cockroaches by cone bioassay tests.

Cyclodiene insecticide resistance in the American cockroaches is related with a single base pair replacement in the GABA receptor or chloride ion channel gene *Rdl* (Thompson et al. 1993). In many parts of the world, the control of cockroaches discontinue with diazinon and chlorpyrifos applications (Reiersen et al. 2005). Unlike the German cockroaches, the commercially available formulations of dishwashing liquids and cleaners were not effective against the American cockroaches (Baldwin and Koehler 2007). Imidacloprid and deltamethrin (2.0-fold), and fipronil (3.9-fold) exhibited moderate level of resistance against adult *P. americana* (Syed et al. 2014). Findings of topically applied entomopathogenic *Metarhizium anisopliae* (Hypocreales: Clavicipitaceae) also emphasize a distinct resistance of nymphs of the American cockroach to *M. anisopliae* (Gutierrez et al. 2016). The American cockroach populations also exhibited resistance against malathion with significantly higher activities of insecticide detoxifying enzymes which were recorded compared to the susceptible control population. The elevated levels and higher enzymatic activity of glutathione S-transferases (GSTs), monooxygenases, and nonspecific esterases are the possible reasons for resistance of malathion and enzymes involved in resistance development (Tahir et al. 2017).

Briefly, *P. americana* is being emerged resistant to cyclodiene, deltamethrin, fipronil, imidacloprid and malathion insecticides, and entomopathogenic *M. anisopliae* (Thompson et al. 1993, Baldwin

and Koehler 2007, Syed et al. 2014, Gutierrez et al. 2016, Tahir et al. 2017). Certainly, a lot of studies need to be done in the future. Unlike the American cockroaches, there are numerous studies performed in the field of insecticide resistance against the German cockroaches. Currently it is well documented that the German cockroaches are being emerged resistant to a wide groups of insecticides including organophosphates, carbamates, pyrethroids, phenyl pyrazoles, spinosad, neonicotinoids, and oxadiazines (Nasirian et al. 2006a–e; Nasirian et al. 2009; Limoe et al. 2010; Nasirian 2010; Nasirian et al. 2011; Paksa et al. 2011, 2012; Ladonni et al. 2013; Naqqash et al. 2016; Nazari et al. 2016; Sanehi Dehkordi et al. 2017).

Although the commercially available formulations of cleaners and dishwashing liquids were equally toxic to adult *B. germanica* cockroaches getting 83–100% mortality with 100% cleaner via an immersion application and 92–100% mortality at 1% dishwashing liquid. However, they were not effective against the adult American cockroaches except for immersion application of dishwashing liquid resulted in a 0.24% LC_{50} (Baldwin and Koehler 2007).

During recent years, LLINs, treated at factory level with insecticide either coated around or incorporated into fibers, have been started to conquer the problems of low retreatment rates, washing, and erratic dose of the insecticide resulting in the dilution of efficacy of the conventional insecticide-treated mosquito nets. Excluding bed bugs, 100% mortality was detected in nontarget household insects including the American cockroaches by cone bioassay tests. In addition to LLINs are highly effective against malaria vectors they moderately impact against non-target household insects (Sharma et al. 2006).

Sewers are being sought to use approved strategies of Integrated Pest Management (IPM) and the materials with minimal environmental impact and low mammalian toxicity can be used. The persistence and efficacy of insecticides in sewers depend on several factors like the rate of organic matters, formulation type, the kind of active matter, the type of cockroach populations, and climatic conditions. It seems emerging of insecticide resistance is the most factors that affects the persistence and efficacy of insecticides. Microencapsulated diazinon and aqueous sprays of wettable powder chlorpyrifos provide an excellent control of cockroaches for at least 9 mo. Emulsifiable concentrate and microencapsulated and chlorpyrifos sprays provide >94.0% reductions of cockroaches for a year (Rust et al. 1991). The product combining piperonyl butoxide with tetramethrin and alfacipermetrin (pyrethroids) also achieve excellent results with cockroach control while the insecticide persistence effects achieve during 1 mo in sewers. These results concordance with outcomes of the other former studies (Rust et al. 1991, Fahiminia et al. 2010, Bueno-Marí et al. 2013). Obviously, the effectiveness of the insecticide formulations for 1-mo control is very little time that this time should be increased. Diazinon and clorpyrifos (organophosphate) insecticides reduce the cockroach populations for only 1 wk (Bueno-Marí et al. 2013). It may be due to insecticide resistance (Tahir et al. 2017) and inadequate insecticide doses.

Application of Dust Formulations

A great way to treat cockroach in the crevices and small cracks is to be dust. Various powders, dusts, and dusters for control of cockroaches are to be boric acid, Delta Dust, Drione Dust, bellow dusters, and electric dusters. Pyrethrins, the active ingredients of the pyrethrum insecticide, are very effective in killing insects but are quite harmless to mammals. When combined with silica gel to form Drione powder, they can be applied for long-term against insects (Schofield and Crisafulli 1980). Drione dust is a very safe product

and also very effective which remains effective as long as it stays dry. An appropriate proprietary dust formulation as little as 50–100 g/manhole including boric acid 35.5%, diatomaceous earth 50%, piperonyl butoxide 10.0%, and pyrethrins 2.0% blown into the system with a commercial DeVilbiss sprayer provide >98% control for at least 3 mo (Reierson et al. 2005). A powder of synergized pyrethrins plus silica gel mixture, boric acid and bendiocarb resulted in an excellent control for at least 1 mo; however, cockroach infestation returned after 3–6 mo of treated shafts. Obviously, the effectiveness of the insecticide formulations for 1 mo control is very little time that this time should be increased. As in the fall populations of the adult cockroaches being the lowest, treatments provide the best results (Rust et al. 1991).

Application of Bait Formulations

Although there is a report using baits failed to provide consistent control of the American cockroaches due to application problems (Rust et al. 1991) or the insect growth regulators (IGRs) are not recommended as an active materials for the control of the American cockroaches in sewers (Bueno-Marí et al. 2013). However, the results of field studies have been indicated that the baits are effective against the cockroaches (Nasirian et al. 2006b, Nasirian 2007, 2008; Wan-Norafikah et al. 2017; Davari et al. 2018) and also the American cockroach species in sewers.

Neonicotinyl and abamectin baits provided rapid success effective control of *P. americana* and relatively inexpensive in sewers. MaxForce FC Roach Killer (fipronil 0.05%) and Pre-Empt, IMAGEL (imidacloprid 2.15%) gel baits provide ≥96% control for 6 mo or longer (Reierson et al. 2005).

Granular ant bait formulations (containing abamectin B1, orthoboric acid, or propoxur) are clearly toxic to the American and German cockroaches. The gel bait formulation of fipronil 0.03% (Goliath) when exploited at the adequate dosages on cement, mud, thatch and wood surfaces could cause >80% mortality of *P. americana* cockroaches in places possessing these types of surfaces. The American cockroaches greatly preferred the commercially available gel baits (0.05% fipronil and 0.6% indoxacarb) for feeding over dog food. The gel bait of indoxacarb 0.6% was highly effective against the American and German cockroaches. *Periplaneta americana* cockroaches ingest the potassium alum affecting mortality. Laboratory and field studies demonstrated the high efficacy of a *B. bassiana* bait formulation against the American and German cockroaches. Although it is important to maximize the bait consumption, the factors enhancing secondary mortality and contacting toxicity should also be considered (Koehler et al. 1991, Appel et al. 2005, Reierson et al. 2005, Srinivasan et al. 2005, Bayer et al. 2012, Anikwe et al. 2014, Salama 2015, Wang et al. 2016).

Baits compared with spray applications possess benefits being inexpensive, ready and easy to use, widely available, having low toxicity and negative side effects, and not needing to apply by a technician (Davari et al. 2018). The applied insecticidal bait formulations provided sustained cockroach elimination during 12 mo and resulted in reduction of asthma morbidity (Rabito et al. 2017). Compared with controls, a field trial placement of boric acid granules to a courtyard eliminate cockroaches with a significant cockroach antigen reduction of buildings (Carlson et al. 2017).

Toxic gel baits are one effective control method for cockroach control. *Periplaneta americana* are thought to prefer toxic baits over other food sources (Porusia et al. 2017). According to the laboratory experiments, the baits were accepted by cockroaches as a food source (Varadinová et al. 2015). However, field *P. americana* strains

tended to visit natural foods more often, and laboratory strains visited insecticide baits more frequently. Field and laboratory strains of *P. americana* cockroaches are not fully attracted to the gel baits when other foods are available around their harborage. Therefore, it needs to be minimized the availability of other food sources when applying gel baits around the cockroach harborage (Porusia et al. 2017). A reasonable manner is using a combination of IPM strategies with strong vector control management such as reforming and cleaning of the environment, spraying, and applying the bait formulations recommending for effective cockroach pest control including *P. americana* (Nasirian 2016, Davari et al. 2018).

To achieve an effective treatment, the gel baits must be applied as a narrow band restricted just below the cover, not deep within. Solid and granular baits administrating by devices or gel baits distributing by cards lower in the manholes of sewers are not as effective. Gel baits which were covered with fungus retrieved from sewer manholes months later stayed toxic indicating prolonged success efficacy against nymphs emerging afterward. Regardless of active ingredient degradation, revival of cockroach populations in some manholes of sewers appearing as a result of the baits may be consumed (Reierson et al. 2005). Therefore, there is a need for replacement of the baits.

Application of Inesfly Paint Insecticide Formulations

An Inesfly paint insecticide is a contact insecticide, specifically formulated for effective, economic, and long-term control. Today, however, insecticidal paints are receiving renewed interest for their potential use against disease vectors. This interest can be attributed to several factors, of which safety of Inesfly paint insecticides, low concentration of active ingredients, organic solvent free, active ingredient gradual releasing, and low application frequency, along with the concerns that should be addressed before this intervention tool achieves widespread application (Hazra 2018). When sewer cockroaches come in contact with Inesfly paint insecticide the mucus secreted by the insect's feet will dissolve the polymers designed to hold the insecticide micro-particles on the treated surface, and the insecticide is then absorbed into the insect's feet killing them typically within 24 to 48 h.

Among several insecticides with different formulations and active substances including Bio-blatocida 100SC (containing diflubenzuron), Diptron EC20 (containing clorpyrifos), Ecorex alfa (containing alphacypermethrin, tetrametrin, and piperonyl butoxide), Empire 20 (containing clorpyrifos), Inesfly 5 A IGR (containing diazinón, clorpyrifos, and pyriproxyfen), Serpa D60 (containing diazinón), and Sumilarv 10 EC (containing pyriproxyfen) apply to sewer shafts for controlling the American cockroaches. The paints with and without insecticide, Inesfly, provide an optimal reduction for up to 3 mo ($P < 0.001$) observing the best products for *P. americana* cockroach populations control. Therefore, it should be noted that the cockroach population reductions, as well as the insecticide persistence effect, were similar in both types of paints in sewers (Bueno-Marí et al. 2013). Paints with insecticide also provide interestingly an optimal control of the American cockroach populations for 3 mo (Bueno-Marí et al. 2013).

One single application of 50–70 g Inesfly paint 5 A IGR per spot provided long-term control of *Blatta orientalis* cockroach populations for 9 mo at this pest infestation of Zaragoza areas in Spain (Delacour-Estrella et al. 2014).

Application of Plant Essential Oils as Insect Repellents

DEPA (N,N-diethylphenylacetamide) displayed residual repellency for 4 wk against *P. americana* cockroaches at 0.5 mg/cm²

concentration (Prakash et al. 1990). Essential oils, produced by plants, have been exhibited to have insecticidal, attractant or repellent properties. These effects are presumed to produce through their interaction with receptors of octopamine. In insects which octopamine is an important biogenic monoamine the functions are as neurohormones, neurotransmitters and neuromodulators (Gross et al. 2014). Briefly essential oils of *Alpinia calcarata* (Zingiberales: Zingiberaceae) freshly cut rhizomes which identified as camphene, camphor, fenchyl acetate 1,8-cineole, β -pinene and α -pinene showed repellent properties in *P. americana*. Essential oils of *Allium sativum* (Lamiales: Lamiaceae), *Brassica nigra* (Brassicales: Brassicaceae) plant and allyl isothiocyanate monoterpenoid component have potential as fumigant insecticidal effects against the American cockroaches (Paranagama and Sujantha Ekanayake 2004, Yilmaz and Tunaz 2013). To achieve practical use, these results need to be evaluated by the field studies.

Recently it has been proved that the *Pogostemon cablin* (Lamiales: Lamiaceae) essential oil of leaves, *Artemisia arborescens* and *A. santolina* (Asterales: Asteraceae), Apiaceae (Apiales) plants, and their major components have good potential as repellents or natural insecticide sources (Yeom et al. 2012, Liu et al. 2015, Yeom et al. 2015) for the German cockroach control, until they will be legally and officially used, take a lot of time (Nazari et al. 2016). The German cockroaches also exhibited high values of repellency exposing to treated filter paper with catnip plant, *Nepeta cataria* (Lamiales: Lamiaceae), the individual nepetalactone isomers or essential oil. Of the two evaluated nepetalactone isomers (Z,E- and E,Z-nepetalactone), *B. germanica* were the most responsive to the E, Z isomer (Schultz et al. 2006). These studies should also be tested in *P. americana* and to achieve practical use the results need to be evaluated by the field studies.

Biocontrol

It is well-known that control with natural enemies is less aggressive and can currently be exploited with less risk than other methods such as chemical control which is the main technique used worldwide to control post-embryonic pest stages (Baggio-Deibler et al. 2018). Chemical control also provide only temporary control, it is recommended that it should be accompanied by other control methods (Ross and Cochran 1992).

Although there was a report that the natural enemies may be inappropriate in the sewer environment. There was no measurable effect on populations of cockroaches in sewer environments after releasing of *Aprostocetus hagenowii* (Hymenoptera: Eulophidae) parasitoid which was reportedly effective on the American and smokybrown cockroaches (*Periplaneta fuliginosa*), but it may be inappropriate due to lack of effectiveness in sewer environment here (Reierson et al. 2005).

So far, natural enemies of *P. americana* including *Evania appendigaster* (Hymenoptera: Evaniidae) and *A. hagenowii*, the parasitoids of *P. americana* oothecae; *Steinernema carpocapsae* (Rhabditida: Steinernematidae) entomopathogenic nematodes; and *Metarhizium anisopliae* and *Beauveria bassiana* (Hypocreales: Clavicipitaceae) entomopathogenic fungi have been successfully used to control *P. americana* cockroaches (Hwang and Chen 2004, Reierson et al. 2005, Fox and Bressan-Nascimento 2006, Hernández-Ramírez et al. 2007, Maketon et al. 2010, Tee et al. 2011a, Hubner-Campos et al. 2013, Gutierrez et al. 2016, Tee and Lee 2017, Baggio-Deibler et al. 2018). But when the natural enemies were applied in the form of baits or along with the baits achieved more successfully results than natural enemies alone (Hwang and Chen 2004, Hernández-Ramírez

et al. 2007, Maketon et al. 2010). The application of *E. appendigaster* parasitoid of the American cockroaches oothecae habitats such as sewers accompanied with baits resulted in effective reduction of the American cockroach populations (Hwang and Chen 2004). The addition of 3 and 5% boric acid to the cockroach diets along with *B. bassiana* produced 82.0 and 92.0% of mortality, respectively which had a good acceptance by the American cockroaches (Hernández-Ramírez et al. 2007). Releasing of *A. hagenowii* parasitoid were also more effective when releases were made at high and middle levels of sewer manholes than at a low level which was placed at the sewer manhole midpoint (Tee et al. 2011a).

The American cockroach oothecae parasitism is affected by host density and days of *E. appendigaster* parasitoid lifetime. The greatest reproductive efficiency of *E. appendigaster* females happened in the first 14 d of their lifetime. The parasitism rates decrease with increasing the host density (Fox and Bressan-Nascimento 2006). Reduced progeny survival of *E. appendigaster* parasitoid due to host cannibalism did not alter the parasitoid's oviposition of females priority for newly cockroach eggs (Tee and Lee 2017). Therefore, in overall to achieve more successful results the releases of parasitoid or natural enemies need frequently to be repeated with appropriate time intervals or it accompanied with the baits, the baits also replaced with the appropriate time intervals.

The Challenges of Finding Environmentally Safe Treatments

The challenges of finding environmentally safe treatments that do not affect urban waters is a very controversial topic. Although valuable researches and reviews about removing the pollutants and insecticides from the urban waters have been implemented. There are valuable treatment technologies and strategies for removal and degradation of persistent and toxic pesticides using nanoparticles and nanotechnology-based multifunctional and highly efficient processes (Kumar Reddy and Lee 2012, Amin et al. 2014, Angelakis and Snyder 2015, Rani et al. 2017). The unique characteristics of nanomaterials such as large surface areas, size, shape, and dimensions making them particularly attractive for urban water treatment applications (Amin et al. 2014). The degradation techniques of insecticides are now advanced using nanomaterials of various kinds such as TiO_2 and Fe and found to be excellent adsorbents and efficient photocatalysts for degrading more or less whole insecticides as well as their toxic metabolites. It is noteworthy that such methodologies are economic, fast and very efficient (Rani et al. 2017).

While it would seem that is wiser to use the strategies that do not lead to environmental contamination from the beginning, in order to solve the problems that human being faced. The actions of these kinds are eliminating of potential cockroach food, water, and shelter sources, closing of crevices or cracks (Orkin 2018), applying materials with minimal environmental impact and low mammalian toxicity (Reierson et al. 2005), having low toxicity and negative side effects including baits (Davari et al. 2018) as well as achieving more successfully results by using natural enemies in the form of baits or along with the baits than natural enemies alone (Hwang and Chen 2004, Hernández-Ramírez et al. 2007, Maketon et al. 2010).

Futuristic Actions

Integrating Health Into the Future Buildings

For promoting healthy environments and behaviors, and mitigating adverse health outcomes, the building designers must redesign, renovate, and reconstruct the future buildings. A key priority in

designing, building, and operating of new and existing buildings also should be based on the health and wellbeing of building occupants. Strategies of green infrastructures, smart buildings, and larger systems should be changed serving and supporting public health goals. To promote health at the level of individual buildings, interventions are also in a manner of enhancing indoor environmental quality and providing opportunities for physical activity.

To measure a building's health impacts and navigate the various programs with using metrics, a 'healthy building' is being built with multiple co-benefits relating to the energy efficiency, environment, economy, planning, society, and transportation (Heidari et al. 2017).

Future Techniques for Control of Cockroaches

Facultative parthenogenesis which may be observed in many animal phyla is an asexual mode of reproduction that females generate offspring without mating with male partner (Katoh et al. 2017) and play an important role in the evolution of insect sex, sociality, and strategies of reproduction (Tanaka and Daimon 2018). Parthenogenesis is frequently more popular than sexual reproduction in some eusocial and subsocial insects (Katoh et al. 2017). As American cockroaches belong to the superfamily Blattodea diverging into eusocial termites and showing facultative parthenogenesis, it is well-suited to address this reproductive issue (Katoh et al. 2017). A type of parthenogenesis which offspring are produced by females without fertilization named as thelytoky are being exhibited in some cockroach species. A study result demonstrates that the American cockroaches exhibit automixis-type thelytoky in which diploidy restoring by gamete duplication or terminal fusion (Tanaka and Daimon 2018).

Bringing together various elements of different pest management strategies and providing a framework for their effective deployment are tactics of push-pull strategies. In the push strategy, stimuli like alarm pheromones, anti-aggregation pheromones, antifeedants, oviposition deterrents, non-host volatiles, and visual distractions are used to mask host apparency or repel or deter the pests away from the resource. In the pull strategy, highly apparent and attractive stimuli like aggregation or sex pheromones, host volatiles, gustatory or oviposition stimulants, and visual stimulants are simultaneously used to attract the pests to other areas such as traps or trap crops concentrating and facilitating elimination there (Cook et al. 2007).

Due to *P. americana* exhibits automixis-type thelytoky, use of this *P. americana* advantage, push-pull strategies and an automated sewer robot, and integrating health into the future buildings (Cook et al. 2007, Heidari et al. 2017, Vaani et al. 2017, Tanaka and Daimon 2018), they may be new approaches of *P. americana* control strategies in the future as futuristic actions. It is well documented that the cockroaches are threatening human health (Nasirian 2010, Nasirian 2016, Davari et al. 2017a, Nasirian 2017a, Schapheer et al. 2018), similar leishmaniosis, mosquitoes, myiasis, tick-borne diseases, pediculosis, and scabies (Poudat and Nasirian 2007; Telmadarraiy et al. 2007; Soleimani-Ahmadi et al. 2009; Nasirian et al. 2014a,b; Shayeghi et al. 2016; Davari et al. 2017b; Martínez-Girón et al. 2017; Gholamian-Shahabad et al. 2018). Cockroach exposure is an important asthma trigger (Rabito et al. 2017), particularly for children with asthma living in homes of cockroach infested. Integrating health into the future buildings and the described below future techniques are the futuristic actions for control of cockroaches.

Although sanitation has been proved not to possess a direct relationship with the domiciliary cockroach infestation levels (Lee and Lee 2000). While cockroaches produce some allergens to be accumulated within their tiny feces and may be persisted invisible in the environment (Varadínová et al. 2015). Buffer environmental

conditions of urbanization allow pest insects expanding their distribution. Several various pest insects, such as synanthropic cockroach organisms, have expanded their distributions by human-modified habitats. Suitable microhabitats for domiciliary cockroaches are generated by human settlements to help them for surviving and establishing to overall of the climatic restrictions (Schapheer et al. 2018). In addition, the buildings of the future must redesign, renovate, and reconstruct for promoting healthy environments and behaviors, and mitigating adverse health outcomes (Heidari et al. 2017). They will be designed and constructed in a way that they are cockroach-proof or impossible to their entering and the survivals are inconceivable.

As *P. americana* has a unique reproduction exhibiting automixis-type thelytoky which diploidy is remade by gamete duplication or terminal fusion (Tanaka and Daimon 2018), in the future it may be a new approach as a *P. americana* control. The new investigations in this context through artificial feeding (Nasirian and Ladonni 2006, Nasirian et al. 2008) may be experimentally performed.

A challenge to locomote animals and engineer seeking in designing agile robots is the information integration from structures of dynamic sensory operating on a moving body. The sensor mechanical tuning is critical for effective control as a tactile sensor is a physical linkage mediating mechanical interactions between environment and body (Mongeau et al. 2014). A sewer automated robot conducting any inspection of sewer lines for cracks, corrosion obstacles, etc. and clearing any blockage within (Vaani et al. 2017) are needed. It is hoped that the robot will be used for control of cockroaches in the future. The tactics of push-pull strategies are bringing together various elements of different pest management strategies and providing a framework for their effective deployment (Cook et al. 2007). They are the future techniques which may be used for control of the American cockroaches in sewers.

Finally a reasonable manner is using a combination of IPM strategies with strong vector control management such as reforming and cleaning of the environment, spraying, and applying the bait formulations recommending for effective cockroach pest control including *P. americana* (Nasirian 2016, Rabito et al. 2017, Davari et al. 2018). A successful tactic to eliminate cockroach allergen exposures is elimination of cockroaches (Sever et al. 2007). Implementing an IPM intervention including education of residents, intensive professional sanitation and extensive insecticidal bait applications resulted in significant reductions of cockroach infestation levels and allergens (Arbes et al. 2003). Environmental and multifaceted interventions have also demonstrated improvement in asthma health outcomes (Arbes et al. 2003, Morgan et al. 2004, Eggleston et al. 2005, Sever et al. 2007, Rabito et al. 2017).

Conclusion

It is well documented that the cockroaches are threatening human health. Cockroaches have proved as potential carriers of the pathogenic or opportunistic bacteria and fungi discovered in nosocomial infections, food-borne poisoning and diseases mostly being drug-resistant, human intestinal parasites and intermediate hosts, and play a role as a major source of allergens causing asthma and other human long-term health issues.

Periplaneta americana is the most important synanthropic invasive and hygienic urban pests. This pest species is an annoyance to human associating with diseases and allergy, and damaging to clothes and documents. *Periplaneta americana* species is also the most important pests of sewer environments colonizing there with high significance of human public health and source of household allergens that need to be controlled. To control *P. americana*, many

studies have been conducted in various fields which has been published in separate papers or notes describing from an angle of the topics. Each of them can be a good lever of *P. americana* control measures. Putting the all levers of its control on the table provide possible using in required conditions. Therefore this practical approach systematic review perform internationally to highlight and provide a detailed of the control of cockroaches in sewers.

Unlike the German cockroaches which its insecticide resistance has been well studied, a few studies have been performed in the field of insecticide susceptibility or resistance against the American cockroaches needing to be done in the future. A recommending manner to achieve a successful *P. americana* cockroach control in sewers is using a combination of IPM strategies with strong vector control management such as masterly resident education, intensive sanitation, environmental and multifaceted interventions, extensive insecticide spraying and bait formulations resulted in reductions of cockroach infestation levels, allergens and asthma health outcomes. As *P. americana* has a unique reproduction and exhibits automixis-type thelytoky, use of this *P. americana* advantage, push-pull strategies and an automated sewer robot, and integrating health into the future buildings, it may be a new strategy of *P. americana* control in the future as futuristic actions.

Acknowledgments

This work did not receive any technical or financial support from any institution and was done by the first author at his own personal expense. The authors declare that they have no conflict of interest.

References Cited

- Alias, U. K. H., and E. B. Retnani. 2018. Diversity and abundance of cockroaches (Insecta: Dictyoptera) in ships at Bau-Bau port. *J. Entomol. Zool. Stud.* 6: 29–34.
- Amin, M. T., A. A. Alazba, and U. Manzoor. 2014. A review of removal of pollutants from water/wastewater using different types of nanomaterials. *Adv. Mater. Sci. Eng.* 2014: 825910.
- Angelakis, A., and S. Snyder. 2015. Wastewater treatment and reuse: past, present, and future. *Water* 7: 4887–4895.
- Anikwe, J. C., F. A. Adetoro, J. A. Anogwih, W. A. Makanjuola, K. A. Kemabonta, and K. L. Akinwande. 2014. Laboratory and field evaluation of an indoxacarb gel bait against two cockroach species (Dictyoptera: Blattellidae, Blattidae) in Lagos, Nigeria. *J. Econ. Entomol.* 107: 1639–1642.
- Appel, A. G., M. J. Eva, and S. R. Sims. 2005. Toxicity of granular ant bait formulations against cockroaches (Dictyoptera: Blattellidae and Blattidae). *Sociobiology* 46: 65–72.
- Arbes, S. J., Jr., M. Sever, J. Archer, E. H. Long, J. C. Gore, C. Schal, M. Walter, B. Nuebler, B. Vaughn, H. Mitchell, et al. 2003. Abatement of cockroach allergen (Bla g 1) in low-income, urban housing: a randomized controlled trial. *J. Allergy Clin. Immunol.* 112: 339–345.
- Atiokeng Tatang, R. J., H. G. Tsila, and J. Wabo Poné. 2017. Medically important parasites carried by cockroaches in Melong subdivision, littoral, Cameroon. *J. Parasitol. Res.* 2017: 7967325.
- Baggio-Deibler, M. V., M. da Costa Ferreira, A. C. Monteiro, A. de Souza-Pollo, and M. V. Franco Lemos. 2018. Management of the American cockroach's oothecae: The potential of entomopathogenic fungi control. *J. Invertebr. Pathol.* 153: 30–34.
- Baldwin, R. W., and P. G. Koehler. 2007. Toxicity of commercially available household cleaners on cockroaches, *Blattella germanica* and *Periplaneta americana*. *Fla. Entomol.* 90: 703–709.
- Bayer, B. E., R. M. Pereira, and P. G. Koehler. 2012. Differential consumption of baits by pest blattid and blattellid cockroaches and resulting direct and secondary effects. *Entomol. Exp. Appl.* 145: 250–259.
- Buczowski, G., R. J. Kopanic, Jr., and C. Schal. 2001. Transfer of ingested insecticides among cockroaches: effects of active ingredient, bait formulation, and assay procedures. *J. Econ. Entomol.* 94: 1229–1236.
- Bueno-Marí, R., A. Bernués-Bañeres, F. J. Peris-Felipo, J. Moreno-Marí, and R. Jiménez-Peydró. 2013. American cockroach control assays in the municipal sewerage system of Valencia (Spain). *Polish Journal of Entomology/Polskie Pismo Entomologiczne* 82: 143–150.
- Carlson, J. C., F. A. Rabito, D. Werthmann, and M. Fox. 2017. The distribution and movement of American Cockroaches in Urban Niches of New Orleans. *Clin. Pediatr. (Phila)* 56: 1008–1012.
- Carrera, L., F. Springer, G. Lipeme-Kouyi, and P. Buffiere. 2016. A review of sulfide emissions in sewer networks: overall approach and systemic modelling. *Water Sci. Technol.* 73: 1231–1242.
- Cook, S. M., Z. R. Khan, and J. A. Pickett. 2007. The use of push-pull strategies in integrated pest management. *Annu. Rev. Entomol.* 52: 375–400.
- Davari, B., A. Hassanzadeh, H. Nasirian, S. Ghiasian, A. Salehzadeh, and M. Nazari. 2017a. Comparison of cockroach fungal contamination in the clinical and non-clinical environments from Iran. *J. Entomol. Acarol. Res.* 49: 109–115.
- Davari, B., F. N. Alam, H. Nasirian, M. Nazari, M. Abdigoudarzi, and A. Salehzadeh. 2017b. Seasonal distribution and faunistic of ticks in the Alashtar county (Lorestan Province), Iran. *Pan Afr Med J.* 27: 1–16.
- Davari, B., S. Kashani, H. Nasirian, M. Nazari, and A. Salehzadeh. 2018. The efficacy of MaxForce and Avion gel baits containing fipronil, clothianidin and indoxacarb against the German cockroach (*Blattella germanica*). *Entomol. Res.* doi:10.1111/1748-5967.12282
- Dehghani, R., M. Atharizadeh, S. G. Moosavi, S. Azadi, M. Rashidi, and A. Paksa. 2014. Analysis of cockroach fauna and frequency in human residential habitats of North of Isfahan, Iran. *International Archives of Health Sciences* 1: 25–29.
- Delacour-Estrella, S., I. Ruiz-Arrondo, A. Muñoz, I. Orensanz, P. Alarcón-Elbal, R. Pinal, and J. Lucientes. 2014. Evaluation of an insecticide paint for the control of cockroaches in the Zaragoza sewage system. *Int. Pest Control* 56: 152.
- Eggleston, P. A., A. Butz, C. Rand, J. Curtin-Brosnan, S. Kanchanaraks, L. Swartz, P. Breyse, T. Buckley, G. Diette, B. Merriman, et al. 2005. Home environmental intervention in inner-city asthma: a randomized controlled clinical trial. *Ann. Allergy. Asthma Immunol.* 95: 518–524.
- EPA. 2016. Urban waste water treatment in 2015. Environmental Protection Agency, Ireland. https://www.epa.ie/pubs/reports/water/wastewater/2015%20urban%20waste%20water%20report_Web%20Version.pdf.
- Esty, B., and W. Phipatanakul. 2018. School exposure and asthma. *Ann. Allergy. Asthma Immunol.* 120: 482–487.
- Fahiminia, M., A. Paksa, A. Zarei, M. Shams, H. Bakhtiari, and M. Norouzi. 2010. Survey of optimal methods for the control of cockroaches in sewers of Qom City. *Iranian Journal of Health and Environment* 3: 19–26.
- Fakoorziba, M. R., F. Eghbal, J. Hassanzadeh, and M. D. Moemenbellah-Fard. 2010. Cockroaches (*Periplaneta americana* and *Blattella germanica*) as potential vectors of the pathogenic bacteria found in nosocomial infections. *Ann. Trop. Med. Parasitol.* 104: 521–528.
- Fox, E. G. P., and S. Bressan-Nascimento. 2006. Biological characteristics of *Evania appendigaster* (L.) (Hymenoptera: Evaniidae) in different densities of *Periplaneta americana* (L.) oothecae (Blattodea: Blattidae). *Biol. Control* 36: 183–188.
- Gholamian-Shahabad, M. R., K. Azizi, Q. Asgari, M. Kalantari, and M. D. Moemenbellah-Fard. 2018. Sandflies species composition, activity, and natural infection with *Leishmania*, parasite identity in lesion isolates of cutaneous leishmaniasis, central Iran. *J. Parasit. Dis.* 42: 252–258.
- Gross, A. D., M. J. Kimber, T. A. Day, P. Ribeiro, and J. R. Coats. 2014. Investigating the effect of plant essential oils against the American cockroach octopamine receptor (Pa oal1) expressed in yeast. In A. D. Gross, J. R. Coats, S. O. Duke and J. N. Seiber (eds.), *Biopesticides: State of the art and future opportunities* (Chapter 9). ACS symposium series 1172: 113–130.
- Gul, S., A. Akar, K. Taj, F. Abbas, N. Rafique, and S. Gul. 2017. Population dynamics of Cockroaches (Pterygota: Blattodea) identified from hospitals of Quetta, Balochistan. *Pure and Applied Biology (PAB)* 6: 1477–1486.
- Gutierrez, A. C., J. A. Machado, R. Hubner-Campos, M. A. Pennisi, J. Rodrigues, C. C. López Lástra, J. J. García, É. K. Fernandes, and C. Luz. 2016. New insights into the infection of the American cockroach *Periplaneta americana* nymphs with *Metarhizium anisopliae* s.l. (Ascomycota: Hypocreales). *J. Appl. Microbiol.* 121: 1373–1383.

- Hazra, D. K. 2018. Pesticidal paints: an integral approach to colour your imagination. *Biodiversity International Journal*. 2: 95–96.
- Heidari, L., M. Younger, G. Chandler, J. Gooch, and P. Schramm. 2017. Integrating health into buildings of the future. *J. Sol. Energy Eng.* 139: 010802.
- Hernández-Ramírez, G., F. Hernández-Rosas, H. Sánchez-Arroyo, and R. Alatorre-Rosas. 2007. Infectivity, age and relative humidity related with susceptibility on nymphs and adults of *Periplaneta americana* to *Metarhizium anisopliae* and *Beauveria bassiana* (Ascomycota: Hypocreales). *Entomotropica*. 22: 27–36.
- Hubner-Campos, R. F., R. N. Leles, J. Rodrigues, and C. Luz. 2013. Efficacy of entomopathogenic hypocrealean fungi against *Periplaneta americana*. *Parasitol. Int.* 62: 517–521.
- Hwang, S. Y., and L. M. Chen. 2004. Effects of four physical treatments of oothecae of *Periplaneta americana* on parasitism and development of parasitic wasp *Evania appendigaster*. *Environ. Entomol.* 33: 1321–1326.
- Kassiri, H., and S. Kazemi. 2012. Cockroaches [*Periplaneta americana* (L.)], Dictyoptera; Blattellidae] as carriers of bacterial pathogens, Khorramshahr County, Iran. *Jundishapur J. Microbiol.* 5: 320–322.
- Katoh, K., M. Iwasaki, S. Hosono, A. Yoritsune, M. Ochiai, M. Mizunami, and H. Nishino. 2017. Group-housed females promote production of asexual ootheca in American cockroaches. *Zoological Lett.* 3: 3.
- Koehler, P. G., T. H. Atkinson, and R. S. Patterson. 1991. Toxicity of abamectin to cockroaches (Dictyoptera: Blattellidae, Blattidae). *J. Econ. Entomol.* 84: 1758–1762.
- Kumar Reddy, D., and S. Lee. 2012. Water pollution and treatment technologies. *J Environ Anal Toxicol.* 2: e103.
- Ladonni, H., A. Paksa, H. Nasirian, A. Doroudgar, and M. Abaie. 2013. Detection of Carbamat and organo phosphorus susceptibility levels in German cockroach in vivo. *Toloo e Behdasht.* 40: 95–105.
- Lee, C. Y., and L. C. Lee. 2000. Influence of sanitary conditions on the field performance of chlorpyrifos-based baits against American cockroaches, *Periplaneta americana* (L.) (Dictyoptera: Blattidae). *J. Vector Ecol.* 25: 218–221.
- Limoe, M., M. Shayeghi, J. Heidari, H. Nasirian, and H. Ladonni. 2010. Susceptibility level of hospital-collected strains of German cockroach *Blattella germanica* (L.) to carbamate and organophosphorous insecticides using surface contact method in Tehran (2007–2008). *J. Kermanshah. Univ. Med. Sci.* 13: 337–343.
- Liu, X. C., Q. Liu, H. Chen, Q. Z. Liu, S. Y. Jiang, and Z. L. Liu. 2015. Evaluation of contact toxicity and repellency of the essential oil of *Pogostemon cablin* leaves and its constituents against *Blattella germanica* (Blattodea: Blattellidae). *J. Med. Entomol.* 52: 86–92.
- Lupo, L. 2017. Cockroaches in drains. *Quality Assurance & Food Safety* <http://www.qualityassurancemag.com/article/pest-management-cockroaches-in-drains/>.
- Maketon, M., A. Hominchian, and D. Hotaka. 2010. Control of American cockroach (*Periplaneta americana*) and German cockroach (*Blattella germanica*) by entomopathogenic nematodes. *Revista Colombiana de Entomología*. 36: 249–253.
- Martínez-Girón, R., C. Martínez-Torre, and H. C. van Woerden. 2017. The prevalence of protozoa in the gut of German cockroaches (*Blattella germanica*) with special reference to *Lophomonas blattarum*. *Parasitol. Res.* 116: 3205–3210.
- Menasria, T., S. Tine, D. Mahcene, L. Benammar, R. Megri, M. Boukoucha, and M. Debazza. 2015. External bacterial flora and antimicrobial susceptibility patterns of *Staphylococcus* spp. and *Pseudomonas* spp. isolated from two household cockroaches, *Blattella germanica* and *Blatta orientalis*. *Biomed. Environ. Sci.* 28: 316–320.
- Mongeau, J. M., A. Demir, C. J. Dallmann, K. Jayaram, N. J. Cowan, and R. J. Full. 2014. Mechanical processing via passive dynamic properties of the cockroach antenna can facilitate control during rapid running. *J. Exp. Biol.* 217: 3333–3345.
- Morgan, W. J., E. F. Crain, R. S. Gruchalla, G. T. O'Connor, M. Kattan, R. Evans, 3rd, J. Stout, G. Malindzak, E. Smartt, M. Plaut, et al.; Inner-City Asthma Study Group. 2004. Results of a home-based environmental intervention among urban children with asthma. *N. Engl. J. Med.* 351: 1068–1080.
- Motevali Haghi, F. M., H. Nikookar, H. Hajati, M. R. Harati, M. M. Shafaroudi, J. Yazdani-Charati, and M. Ahanjan. 2014a. Evaluation of bacterial infection and antibiotic susceptibility of the bacteria isolated from cockroaches in educational hospitals of Mazandaran University of medical sciences. *Bulletin of Environment, Pharmacology and Life Sciences*. 3: 25–28.
- Motevali Haghi, S., S. Aghili, S. Gholami, B. Salmanian, S. Nikokar, M. Khangolzadeh, and H. Geravi. 2014b. Isolation of medically important fungi from cockroaches trapped at hospitals of Sari, Iran. *Bulletin of Environment, Pharmacology and Life Sciences*. 3: 29–36.
- Naqqash, M. N., A. Gökçe, A. Bakhsh, and M. Salim. 2016. Insecticide resistance and its molecular basis in urban insect pests. *Parasitol. Res.* 115: 1363–1373.
- Nasirian, H. 2007. Duration of fipronil and imidacloprid gel baits toxicity against *Blattella germanica* strains of Iran. *J. Arthropod Borne Dis.* 1: 40–47.
- Nasirian, H. 2008. Rapid elimination of German Cockroach, *Blattella germanica*, by fipronil and imidacloprid gel baits. *J. Arthropod Borne Dis.* 2: 37–43.
- Nasirian, H. 2010. An overview of German cockroach, *Blattella germanica*, studies conducted in Iran. *Pak. J. Biol. Sci.* 13: 1077–1084.
- Nasirian, H. 2016. New aspects about *Supella longipalpa* (Blattaria: Blattellidae). *Asian Pac. J. Trop. Biomed.* 6: 1065–1075.
- Nasirian, H. 2017a. Contamination of cockroaches (Insecta: Blattaria) to medically fungi: A systematic review and meta-analysis. *J. Mycol. Med.* 27: 427–448.
- Nasirian, H. 2017b. Infestation of cockroaches (Insecta: Blattaria) in the human dwelling environments: A systematic review and meta-analysis. *Acta Trop.* 167: 86–98.
- Nasirian, H. 2019. Recent cockroach bacterial contamination trend in the human dwelling environments: A systematic review and meta-analysis. *Bangladesh J. Med. Sci.* 18: in press.
- Nasirian, H., and H. Ladonni. 2006. Artificial bloodfeeding of *Anopheles stephensi* on a membrane apparatus with human whole blood. *J. Am. Mosq. Control Assoc.* 22: 54–56.
- Nasirian, H., H. Ladonni, and H. Vatandoost. 2006a. Duration of fipronil topical application toxicity in *Blattella germanica* field population strains. *Pakistan J Biol Sci.* 9: 800–804.
- Nasirian, H., H. Ladonni, H. Vatandoost, M. Shayeghei, and A. Poudat. 2006b. Laboratory performance of 0.05% fipronil and 2.15% imidacloprid gel baits against German cockroaches, *Blattella germanica*. *Hormozgan Med. J.* 10: 24–25.
- Nasirian, H., H. Ladoni, B. Davari, M. Shayeghi, Y. Ershadi, M. Reza, and H. Vatandoost. 2006c. Effect of fipronil on permethrin sensitive and permethrin resistant strains of *Blattella germanica*. *Scientific Journal of Kurdistan University of Medical Sciences*. 11: 33–41.
- Nasirian, H., H. Ladonni, M. Shayeghi, H. Vatandoost, M. Yaghoobi-Ershadi, Y. Rassi, M. Abolhassani, and M. Abaei. 2006d. Comparison of permethrin and fipronil toxicity against German cockroach (Dictyoptera: Blattellidae) strains. *Iran. J. Public Health.* 35: 63–67.
- Nasirian, H., H. Ladonni, M. Shayeghi, H. Vatandoost, Y. Rassi, M. Y. Ershadi, J. Rafinejad, and H. Basseri. 2006e. Duration of fipronil WHO glass jar method toxicity against susceptible and feral German Cockroach strains. *Pak. J. Biol. Sci.* 9: 1955–1959.
- Nasirian, H., H. Ladonni, and A. Poudat. 2008. Mass rearing of *Anopheles stephensi* on human blood by artificial feeding under laboratory conditions. *Bimonthly Journal of Hormozgan University of Medical Sciences*. 12: 137–142.
- Nasirian, H., H. Ladonni, M. Shayeghi, and M. S. Ahmadi. 2009. Iranian non-responding contact method German cockroach permethrin resistance strains resulting from field pressure pyrethroid spraying. *Pak. J. Biol. Sci.* 12: 643–647.
- Nasirian, H., H. Ladonni, M. Aboulhassani, and M. Limoe. 2011. Susceptibility of field populations of *Blattella germanica* (Blattaria: Blattellidae) to spinosad. *Pak. J. Biol. Sci.* 14: 862–868.
- Nasirian, H., S. M. T. Sadeghi, B. Vaziranzadeh, and S. H. Moosa-Kazemi. 2014a. New record of *Aedes vittatus* and *Culiseta subochrea* (Diptera: Culicidae) and their distribution from Shadegan Wetland, South Western Iran. *Journal of Entomology and Zoology Studies*. 2: 271–275.

- Nasirian, H., B. Vazirianzadeh, S. M. Taghi Sadeghi, and S. Nazmara. 2014b. *Culiseta subochrea* as a bioindicator of metal contamination in Shadegan International Wetland, Iran (Diptera: Culicidae). *J. Insect Sci.* 14.
- Nazari, M., B. A. Motlagh, and H. Nasirian. 2016. Toxicity of Cypermethrin and Chlorpyrifos Against German Cockroach [*Blattella germanica* (Blattaria: Blattellidae)] Strains from Hamadan, Iran. *Pak. J. Biol. Sci.* 19: 259–264.
- Noureddin, E. M., and H. Farrag. 2008. Population density of cockroach species and magnitude of their infestation in Jeddah Province, Saudi Arabia. *Flora And Fauna (Jhansi)*. 14: 259–267.
- Orkin, L. 2018. How to get rid of waterbugs or sewer roaches? <https://www.orkin.com/ask-the-orkin-man/how-to-get-rid-of-sewer-roaches-or-water-bugs/>.
- Page, K. 2012. Role of cockroach proteases in allergic disease. *Curr. Allergy Asthma Rep.* 12: 448–455.
- Pai, H. H. 2013. Multidrug resistant bacteria isolated from cockroaches in long-term care facilities and nursing homes. *Acta Trop.* 125: 18–22.
- Paksa, A., H. Ladonni, and H. Nasirian. 2011. Detection of malathion and chlorpyrifos resistance mechanism in German cockroaches (*Blattella germanica*, Insecta: Blattodea: Blattellidae) using piperonyl butoxide and tributyl phosphorotrithioate. *Bimonthly Journal of Hormozgan University of Medical Sciences*. 15: 243–253.
- Paksa, A., H. Ladonni, and H. Nasirian. 2012. Comparison of PBO and DEF effects on creating bendiocarb and carbaryl insecticide resistance in German cockroach. *Scientific Journal of Kurdistan University of Medical Sciences*. 17: 91–101.
- Paranagama, P. A., and E. M. D. Sujantha Ekanayake. 2004. Repellent properties from essential oil of *Alpinia calcarata* Rosc. against the American cockroach, *Periplaneta americana*. *J. Natl. Sci. Found. Sri Lanka* 32: 1–12.
- Porusia, M., A. Poynter, S. Dhesi, and Z. Lynch. 2017. The bait preference of American cockroach (*Periplaneta americana*): field and laboratory strains. *Adv. Sci. Lett.* 23: 3558–3561.
- Poudat, A., and H. Nasirian. 2007. Prevalence of pediculosis and scabies in the prisoners of Bandar Abbas, Hormozgan province, Iran. *Pak. J. Biol. Sci.* 10: 3967–3969.
- Prakash, S., C. P. Srivastava, S. Kumar, K. S. Pandey, M. P. Kaushik, and K. M. Rao. 1990. N,N-diethylphenylacetamide—a new repellent for *Periplaneta americana* (Dictyoptera: Blattidae), *Blattella germanica*, and *Supella longipalpa* (Dictyoptera: Blattellidae). *J. Med. Entomol.* 27: 962–967.
- Rabito, F. A., J. C. Carlson, H. He, D. Werthmann, and C. Schal. 2017. A single intervention for cockroach control reduces cockroach exposure and asthma morbidity in children. *J. Allergy Clin. Immunol.* 140: 565–570.
- Rani, M., U. Shanker, and V. Jassal. 2017. Recent strategies for removal and degradation of persistent & toxic organochlorine pesticides using nanoparticles: A review. *J. Environ. Manage.* 190: 208–222.
- Reiersen, D. A., M. K. Rust, and E. Paine. 2005. Control of American cockroaches (Dictyoptera: Blattidae) in sewer systems, pp. 141–148. *In* Fifth International Conference on Urban Pests, Singapore, 11–13 July 2005. International Conference on Urban Pests (ICUP).
- Ross, M. H., and D. G. Cochran. 1992. Strain differences in the response of German cockroaches (Dictyoptera: Blattellidae) to emulsifiable concentrates. *J. Econ. Entomol.* 85: 1201–1208.
- Rust, M. K., D. A. Reiersen, and K. H. Hansgen. 1991. Control of American cockroaches (Dictyoptera: Blattidae) in sewers. *J. Med. Entomol.* 28: 210–213.
- Salama, E. M. 2015. A novel use for Potassium Alum as controlling agent against *Periplaneta americana* (Dictyoptera: Blattidae). *J. Econ. Entomol.* 108: 2621–2629.
- Salehzadeh, A., P. Tavacol, and H. Mahjub. 2007. Bacterial, fungal and parasitic contamination of cockroaches in public hospitals of Hamadan, Iran. *J. Vector Borne Dis.* 44: 105–110.
- Sanei Dehkordi, A., Y. Salim Abadi, H. Nasirian, T. Hazratian, M. A. Gorouhi, S. Yousefi, and A. Paksa. 2017. Synergists action of piperonyl butoxide and S,S,S-tributyl phosphorotrithioate on toxicity of carbamate insecticides against *Blattella germanica*. *Asian Pac. J. Trop. Med.* 10: 981–986.
- Schapheer, C., G. Sandoval, and C. A. Villagra. 2018. Pest cockroaches may overcome environmental restriction due to anthropization. *J. Med. Entomol.* 55: 1357–1364.
- Schofield, E. K., and S. Crisafulli. 1980. A safer insecticide for herbarium use. *Brittonia*. 32: 58–62.
- Schultz, G., C. Peterson, and J. Coats. 2006. Natural insect repellents: activity against mosquitoes and cockroaches in Natural Products for Pest Management, pp. 168–181. *In* A. M. Rimando and S. O. Duke (eds.), ACS Symposium Series. American Chemical Society, Washington, DC.
- Sever, M. L., S. J. Arbes, Jr, J. C. Gore, R. G. Santangelo, B. Vaughn, H. Mitchell, C. Schal, and D. C. Zeldin. 2007. Cockroach allergen reduction by cockroach control alone in low-income urban homes: a randomized control trial. *J. Allergy Clin. Immunol.* 120: 849–855.
- Shammay, A., E. C. Sivret, N. Le-Minh, R. Lebrero Fernandez, I. Evanson, and R. M. Stuetz. 2016. Review of odour abatement in sewer networks. *J. Environ. Chem. Eng.* 4: 3866–3881.
- Sharma, S. K., A. K. Upadhyay, M. A. Haque, K. Padhan, P. K. Tyagi, M. A. Ansari, and A. P. Dash. 2006. Wash resistance and bioefficacy of Olyset net—a long-lasting insecticide-treated mosquito net against malaria vectors and nontarget household pests. *J. Med. Entomol.* 43: 884–888.
- Shayeghi, M., N. Piazak, A. Gollampoor, H. Nasirian, and M. Abolhassani. 2016. Tick-borne relapsing fever in Sabzevar (Khorasan Razavy Province), North-Eastern Iran. *Bangladesh Journal of Medical Science*. 15: 551–555.
- Soleimani-Ahmadi, M., H. Nasirian, A. N. Gheshmi, and M. Y. Ershadi. 2009. Human extensive head Skin myiasis. *Iran. J. Public Health*. 38: 134–138.
- Sookrung, N., O. Reamtong, R. Poolphol, N. Indrawattana, W. Seesuy, N. Saelim, P. Tantipikorn, C. Bunnag, W. Chaicumpa, and A. Tungtrongchitr. 2018. Glutathione S-transferase (GST) of American cockroach, *Periplaneta americana*: classes, isoforms, and allergenicity. *Sci. Rep.* 8: 484.
- Srinivasan, R., P. Jambulingam, S. Subramanian, and M. Kalyanasundaram. 2005. Laboratory evaluation of fipronil against *Periplaneta americana* & *Blattella germanica*. *Indian J. Med. Res.* 122: 57–66.
- Sulaiman, I. M., M. Anderson, M. Khristova, K. Tang, N. Sulaiman, E. Phifer, S. Simpson, and K. Kerdahi. 2011. Development of a PCR-restriction fragment length polymorphism protocol for rapid detection and differentiation of four cockroach vectors (group I “Dirty 22” species) responsible for food contamination and spreading of foodborne pathogens: public health importance. *J. Food Prot.* 74: 1883–1890.
- Syed, R., F. Manzoor, R. Adalat, A. Abdul-Sattar, and A. Syed. 2014. Laboratory evaluation of toxicity of insecticide formulations from different classes against American cockroach (Dictyoptera: Blattidae). *J. Arthropod. Borne. Dis.* 8: 21–34.
- Tachbele, E., W. Erku, T. Gebre-Michael, and M. Ashenafi. 2006. Cockroach-associated food-borne bacterial pathogens from some hospitals and restaurants in Addis Ababa, Ethiopia: Distribution and antibiograms. *Journal of Rural and Tropical Public Health*. 5: 34–41.
- Tahir, H., R. Mustafa, A. Khan, K. Samiullah, S. Abbas, K. Zahra, A. Yaqub, S. Naseem, and R. Yaqoob. 2017. Toxicity and resistance of American cockroach, *Periplaneta americana* L. (Blattodea: Blattidae) against malathion. *Afr. Entomol.* 25: 361–366.
- Tanaka, M., and T. Daimon. 2018. First molecular genetic evidence for automictic parthenogenesis in cockroaches. *Insect Sci.* doi:10.1111/1744-7917.12572
- Tang, Q., H. Jiang, Y. Li, T. Bourguignon, and T. A. Evans. 2016. Population structure of the German cockroach, *Blattella germanica*. *Biol. Invasions* 18: 2391–2402.
- Tee, H. S., and C. Y. Lee. 2017. Cockroach oothecal parasitoid, *Evania appendigaster* (Hymenoptera: Eviinidae) exhibits oviposition preference towards oothecal age most vulnerable to host cannibalism. *J. Econ. Entomol.* 110: 2504–2511.
- Tee, H. S., A. R. Saad, and C. Y. Lee. 2011a. Evaluation of *Aprostocetus hagenowii* (Hymenoptera: Eulophidae) for the control of American cockroaches (Dictyoptera: Blattidae) in sewers and crevices around buildings. *J. Econ. Entomol.* 104: 2031–2038.
- Tee, H. S., A. R. Saad, and C. Y. Lee. 2011b. Population ecology and movement of the American cockroach (Dictyoptera: Blattidae) in sewers. *J. Med. Entomol.* 48: 797–805.
- Telmadarraiy, Z., H. Nasirian, H. Vatandoost, M. Aboulhassani, M. Tavakoli, Z. Zarei, O. Banafshi, J. Rafinejad, S. Salarielac, and F. Faghihi. 2007. Comparative susceptibility of cypermethrin in *Ornithodoros lahorensis* Neuman and *Argas persicus* Oken (Acari: Argasidae) field populations. *Pak. J. Biol. Sci.* 10: 4315–4318.

- Thompson, M., J. C. Steichen, and R. H. French-Constant. 1993. Conservation of cyclodiene insecticide resistance-associated mutations in insects. *Insect Mol. Biol.* 2: 149–154.
- TICLP. 2017. How to keep cockroaches out of your drains. <https://www.terminix.com/blog/diy/remove-roaches-from-drain/>.
- Vaani, I., S. J. Sushil, U. V. Kunjamma, A. Ramachandran, V. T. Bai, and B. Thyla. 2017. BhrtyArtana (A pipe cleaning and inspection robot), pp. 422–425. *In* Sensing, Signal Processing and Security (ICSSS), 2017 Third International Conference on, 4–5 May 2017, Chennai, India. IEEE.
- Varadínová, Z., D. Frynta, R. Aulický, and V. Stejskal. 2015. Detection of cockroach faeces: consumption of fluorescent bait and production of UV-light-detectable faeces from German cockroach, *Blattella germanica*. *Entomol. Exp. Appl.* 155: 167–175.
- Vythilingam, I., and Y. Sutivigit. 1994. Comparative susceptibility of *Periplaneta americana* (L) to five pyrethroid insecticides. *Southeast Asian J. Trop. Med. Public Health* 25: 528–531.
- Wagan, T. A., H. Chakira, H. Hua, Y. He, and J. Zhao. 2017. Biological activity of essential oil from *Piper nigrum* against nymphs and adults of *Blattella germanica* (Blattodea: Blattellidae). *J. Kansas Entomol. Soc.* 90: 54–62.
- Wang, D., Y. Wang, X. Zhang, H. Liu, and Z. Xin. 2016. Laboratory and field evaluation of *Beauveria bassiana* bait against two cockroach species (Dictyoptera: Blattellidae, Blattidae) in Jinan City, East China. *Biocontrol Sci. Technol.* 26: 1683–1690.
- Wan-Norafikah, O., H. Lee, M. Sofian-Azirun, A. Nura-Muna, and C. Chen. 2017. Toxicity of imidacloprid gel bait against laboratory strain of *Periplaneta americana* (L.) (Dictyoptera: Blattidae) and *Blattella germanica* (L.) (Dictyoptera: Blattellidae). *Jurnal Sains Kesihatan Malaysia* (Malaysian Journal of Health Sciences). 15: 37–42.
- Williams, C. 2016. Yes, there are cockroaches in your sewer system! on February 18, 2016 <http://www.colonialpest.com/yes-there-are-cockroaches-in-your-sewer-system/>.
- Yeom, H. J., J. S. Kang, G. H. Kim, and I. K. Park. 2012. Insecticidal and acetylcholine esterase inhibition activity of Apiaceae plant essential oils and their constituents against adults of German cockroach (*Blattella germanica*). *J. Agric. Food Chem.* 60: 7194–7203.
- Yeom, H. J., C. S. Jung, J. Kang, J. Kim, J. H. Lee, D. S. Kim, H. S. Kim, P. S. Park, K. S. Kang, and I. K. Park. 2015. Insecticidal and acetylcholine esterase inhibition activity of Asteraceae plant essential oils and their constituents against adults of the German cockroach (*Blattella germanica*). *J. Agric. Food Chem.* 63: 2241–2248.
- Yilmaz, Y. B., and H. Tunaz. 2013. Fumigant toxicity of some plant essential oils and their selected monoterpenoid components against adult American cockroach, *Periplaneta americana* (Dictyoptera: Blattidae). *Turk. Entomol. Derg.* 37: 319–328.
- Zhu, J.-J., S. Yao, X. Guo, B.-S. Yue, X.-Y. Ma, and J. Li. 2018. Bioactivity-guided screening of wound-healing active constituents from American cockroach (*Periplaneta americana*). *Molecules* 23: 101.