Application of Green Synthesized Nanoparticles against malaria vector Anopheles stephensi

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Abstract

This chapter summarizes scientifically the role of nano-materials as means of mosquito control against discrete life stages of Anopheles stephensi. Malaria is transmitted across the temperate country, mainly in urban areas by the vector An. stephensi. But, due to the over exploitation of the synthetic insecticides, mosquito populations get resistance against it and it pushes the mosquito control strategies in the verge of massive menace. A handful of other ways, apart from the chemical insecticides, are there to check the vector

population, but unfortunately those courses of actions also manifested misfired in many instances. Now, by using an eco-friendly, innocuous, cost effective, biodegradable and selective product, which aids in malaria extermination, is an alternative efficacious proposition. The green synthesized nanoparticle as mosquito control agents is eventually the new domain revealed by the fusion of the nanotechnology domain and the vector management domain. This chapter accounts for the already documented role of nano-materials as means of mosquito control against An. stephensi.

Keywords: Nanoparticles, Anopheles stephensi , vectors, malaria, larvicides.

Introduction

Arthropod are the possible vectors of diverse abhorrent pathogens and parasites, and mosquitoes (Diptera: Culicidae), are one of the main obnoxious member among them; the flying miniscule devil holds the status of the potential biological vector of diverse fatal human maladies like malaria, dengue, filariasis, Japanese encephalitis, chikungunya, yellow fever, Zika fever and West Nile fever etc. affecting mankind worldwide in innumerable manner. In tropical countries, Anopheles, Culex, and Aedes, these three genera of little winged devils cause millions of deaths on a yearly basis. Anopheles stephensi conveys the pathogen, causative agent of malaria, Plasmodium sp, the unicellular protozoa. The discovery of artemisinin and the invention of the first vaccine against Plasmodium [i.e. RTS, S/AS01 (RTS, S)] in 2015 (White, 2015; WHO, 2015a; Benelli and Mehlhorn,

2016), manages to drop the malaria infection rate but nevertheless the exigency to improve the malaria prevention and control policy prevails. Around 216 million individuals are infected with malaria worldwide, from 91 countries and in India , around 13 million delineated cases arise (WMR, 2017; GHO, 2017). On an annual basis, malaria affects about 300-500 million global population approximately and the number of threatened population is around 2.4 billion people, with around 1.1-2.7 million demises (WHO, 2005). So, to exterminate malaria worldwide, the foremost step is mosquito control. Worldwide researchers have tried numerous master plans; mosquito control is executed either at adult phase inside dwelling places or at “wriggler” phase in aquatic habitat, excluding the exclusion and personal protection.

But, the non-biodegradable insecticides is responsible for the serious impairment caused to non-target life-forms sharing the similar habitat with the mosquitoes as well as the boundless use of synthetic insecticides against the target mosquito vector population, constrains the vector population to develop resistance against it. (Liu et al., 2006; Yang et al., 2002).

Thus, the urge to innovate a substitutional eco-friendly, cost-efficient, biodegradable proposition for the sake of mosquito vector population control, is a top-level necessity. At this moment in time, plant origin insecticide having aforementioned qualities, is fabricated by the researchers. Another advantageous quality of this type of insecticide is, being safe for the non target life forms. On this

basis, nanotechnology is revealed as the finest way to create a revolution in the upcoming time in regard to vector population control (Rawani et al., 2013; Haldar et al., 2013).

In industrial, chemical, biological, physical fields, nanotechnologies appeared to be pertaining. The drug & gene delivery, pest management, tissue engineering and in many more domains of biological field, diverse nano-biotechnology applications are present.thus, green originated nanoparticles (NPs) from plant extracts are at this moment, a suitable alternative proposition in vector management domain (Albrecht et al., 2006). In the contemporary review, the plant originated various NPs (gold, silver, zinc etc.) possessing mosquito larvicidal potentiality against An. stephensi, the notorious malarial vector, is summarized.

Nanotechnology , the upcoming time green revolution, against malaria vector control

With the magnificent utilization in the bioscience domain, nanotechnology leads the way of revolution in the world by revealing a brand new opportunity of technology in science, including NPs, nano-channels, nana-tubes, nano-pores etc (Fortina et al., 2005). Nanoparticles of size range 10-1000 nm, are quite solid particles. “nano” originated from “dwarf”, a Greek word. In scientific terms, “nano” implies 10-9, or 1 billionth of a meter. Analytically, from the utilization of nanometer size particles in various applications, the word “nanotechnology” originated. Some of the unique attributes of these NPs are unanticipated vigor, more voltaic conductivity, high chemical reactivity and high magnetic powers. From

various techniques of preparation,nanoparticles, nanospheres or nanocapsules can be generated. In spite of the fact that chemical and physical procedures are more favored and extensively utilized for nanoparticle synthesis, their application is narrowed due to the non-biodegradable property and the allied environmental toxicity of the products. By generating various kinds of nanoparticles from plant essence, implementation of nanotechnology have been expanded in the domain of mosquito control.stem, leaf, seed, root, fruits, latex etc. various plant portions are utilized for bio-fabrication of metal NPs with the assistance of the polyphenols obtained from those herbal origins. By using various latest scientific appliances like Fourier Transform Infrared Spectroscopy (FT-IR), Scanning and Transmission Electron Microscopy (SEM and TEM), UV-VIS spectroscopy, X-ray Diffraction (XRD), the attribution of fabricated nanoparticles were accomplished; by this technique the valuable knowledge about the structure and size, required details regarding the functional group can be revealed too. (Adhikari et al., 2013). Economical or cost-efficient, eco-friendly, recyclable and robust products and their broadly extensive span of applications are the sweet advantages of the plant synthesized NPs. (Postma et al., 1999; Salam et al., 2012).

Plant fabricated nanoparticles against malarial vector Anopheles stephensi : an eco-friendly trend

At this moment, a tremendous number of efficacious green based compounds are utilized to fabricate metal nanoparticles , which have magnificent potential to be proved

as victorious mosquitocidal agent in extracellular condition, even in field conditions (Rajan et al., 2015; Amerasan et al., 2016). The mosquito larvicidal, pupicidal and adulticidal potencies of NPs , are at present evaluated by the virtue of a majority of experiments. (Subramaniam et al., 2016).

To fabricate metal nanoparticles of various size and shape with fatal effect against mosquito vectors, the green materials are utilized as reducing and sustaining agent.for instance, cubical and spherical shaped silver nanoparticles are produced by utilizing Carissa spinarum leaves (Govindarajan et al., 2016a) and Azadirachta indica (Murugan et al., 2015a) respectively.

Silver nanoparticles (Ag-NPs) are fabricated utilizing the seed essence from Sterculia foetida, a wild Indian almond tree which revealed a propitious effect against the larvae of An. stephensi , the notorious malarial vector, with the LC_{50} value less than 4.5 ppm; revealed by the experiment of Rajasekharreddy and Rani (2014) . A solitary exposure to 30 ppm concentration of silver nanoparticles originated from Sargassum muticum, against the vector An. stephensi, causes 100% reduction in egg hatchability (Madhiyazhagan et al. 2015) . Plant fabricated Ag-NPs revealed promising larvicidal effects against 1^{st}-4^{th} instar larvae; the aforementioned experiment is performed by utilizing Euphorbia hirta leaf extract against the malarial vector An. stephensi (Priyadharshini et al., 2012) 10.14, 16.82, 21.51, 27.89 ppm and 31.98, 50.38, 60.09, 69.94 ppm are LC_{50} and LC_{90} values respectively against the larvae and 34.52 and

79.76 ppm reported as the LC_{50} and LC_{90} values of pupae, respectively. Patil et al. (2012a, 2012b) fabricated Ag-NPs by utilizing the latex of Plumeria rubra and P. daemia and used in experiment against the larvae of An. stephensi. NPs revealed propitious outcomes after 24 hr exposure where 1.10 ppm and 1.74 ppm were the LC_{50} values against the 2^{nd} and 4^{th} larval instars of An. stephensi.

Ag-NPs fabricated by utilizing aqueous foliage extracts of various plant species like Euphorbia tirucalli, Jatropha gossypifolia, Alstonia macrophylla and Pedilanthus tithymaloides (Borase et al. , 2013) and its larvicidal potency was evaluated against the 2^{nd} and 4^{th} instars larvae of the vector An. stephensi. The LC_{50} values were from 5.90 to 8.04 ppm and 4.90 to 9.55 ppm in case of 2^{nd} and 4^{th} instar larvae respectively. In an experiment the fabricated steady, economical Ag-NPs with desiccated green fruits of Drypetes roxburghii revealed its Cent percent larval mortality after 24 hour of exposure., against 2^{nd}, 3^{rd} and 4^{th} instars larvae of the vector An. stephensi. at 10 ppm concentration, (Haldar et al.,2013)

Rawani et al. (2013) delineated that Ag-NPs fabricated by Solanum nigrum foliages and berry extract manifest promising mosquito larvicidal features against all the larval stages of the vector An. stephensi. The highest larval mortality is exhibited when the concentration is 10 ppm with the LC_{50} values of 1.33 ppm, 1.59 ppm and 1.56 ppm for dry foliages, fresh foliages and berries respectively. In an evaluation Adhikari et al. (2018) produced Ag-NPs by using

aqueous extracts of foliages of Swietenia mahagoni and implemented against the 3rd instar larvae of An. stephensi. The aqueous silver ions have been reduced by the foliage aqueous extract to generate steadfast Ag-NP. The Ag-NPs solution can exhibit cent percent larval mortality, at 80 ppm concentration after 48 h of exposure.

Foliages of Heliotropium indicum were utilized to fabricate Ag-NPs by Veerakumar et al., (2014). It shows propitious larvicidal consequences against late 3rd instar larvae of An. stephensi , where the exhibited LC_{50} and LC_{90} values are 68.73 µg/mL and 121.07 µg/mL respectively.

In 2012, Arjunan et al. confirmed that Ag-NPs from Annona squamosa foliage extract shows astonishing larvicidal efficacy against the malarial vector An. stephensi where 0.41 ppm is the exhibited LC_{50} value. Jayaseelan et al., (2012) declared that Musa paradisiaca foliage was utilized to synthesize Ag NPs possessing noteworthy larvicidal activity against malarial vector An. stephensi. Against the mosquito larvae the applied solutions of Ag-NPs were revealed in 1, 2, 3, 4 and 5 mg/mL concentration. After 24 hour of exposure, cent percent larval mortality was reported at 5 mg/mL concentration.

From the mesocarp layer extract of Cocos nucifera, an efficacious mosquitocidal Ag-NPs fabricated by Roopan et al., (2013). A Nano-particle solution was applied in 0.25, 0.5, 1.5, 2, 4 mg/mL concentrations against the larvae of the malarial vector An. stephensi, a nano-particle solution was implemented in 0.25, 0.5, 1.5, 2, 4 mg/mL concentration.

Propitious larval mortality was reported with 87.24 ppm LC_{50} value after 72 hour of exposure.

In another report, the larvicidal, pupicidal and repellent efficacies were proved by the plant originated silver nanoparticles fabricated by the aqueous extracts of foliages of Adiantum capillus against vector An. stephensi, where in case of 1st instar larvae cent percent larval mortality was exhibited after 1 h of exposure (Mary et al., 2013).

established the larvicidal activity of plant synthesized Ag-NPs utilizing Chomelia asiatica foliage extracts against the late 3rd instar larvae of malarial vector An. stephensi was confirmed by Muthukumaran et al. (2015). 17.95 and 33.03 µg/mL values were the LC_{50} and LC_{90} values of the nanoparticle solutions respectively. Bhuvaneswari et al., (2016) reported astounding larvicidal activity of Ag-NPs using the foliage extract of Belosynapsis kewensis against the 4th instar larvae of the vector An. stephensi, where 78.4 ppm and 144.7 ppm were exhibited as the effective LC_{50} and LC_{90} values respectively.

Govindarajan et al. (2016) revealed that plant-fabricated Ag-NP synthesized with the foliage extracts of Malva sylvestris have propitious consequences against the larvae of the malarial vector An. stephensi with 10.33 µg/mL as the obligatory LC_{50} value. Apart from silver, there is gold, cobalt, zinc, copper, nanoparticles also, for instance, gold nanoparticles (Au-NPs) is produced by Murugan et al. in 2015 by using the Cymbopogon citratus extract which executed a role of capping and reducing agent. After characterization the

Au-NPs were implemented against both the larvae and pupae stages of the vector An. stephensi.

Fungus originated nanoparticles against malarial vector Anopheles stephensi:

The plant originated NPs are at present a revolutionary solution because of its cost-efficient property, eco-friendliness and biodegradability (Suman et al., 2013). After the utilization of various plants to fabricate the remarkable NPs, various funguses are also implemented in this field of work. Ag-NPs of size ranges from 14–25 nm and 10–18 nm, were synthesized with the help of Penicillium expansum HA2N and Aspergillus terreus HA1N, the two separated fungal strains respectively. Salunkhe et al. (2011) have synthesized a fungi derived NPs by utilizing Cochliobolus lunatic, a filamentous fungus; it furthermore aided in reduction of the metallic NPs. These fungi based NPs possess significant potentialities to control An. stephensi. Gold and silver NPs, fabricated from Aspergillus niger, Chrysosporium tropicum exhibited astonishing mosquitocidal efficacy against malarial vectors, furthermore safe for non-target life-forms. In another report by using the soil fungi Chrysosporium keratinophilum and Verticillium lecanii AG-NPs and Au-NPs were synthesized and a propitious outcome revealed against An. stephensi larvae and pupae life stages. (Soni and Prakash, 2012, 2013a, 2013b, 2014).

Trichoderma harzianum , an entomopathogenic fungus, fundamentally utilized as a biological pest control agent, at present can be utilized to produce metallic NPs. The NPs

were used against various life stages of An. stephensi to reduce its population.

Nanoparticles with the biocontrol agent: bacteria against malarial vector Anopheles stephensi:

Like formerly surveyed different plant portions and fungus, to fabricate the Ag-NPs, at present both Gram-positive and Gram-negative bacteria have also been utilized. Some bacteria possess the capability to synthesize extracellular as well as intracellular AgNPs, like Calothrix pulvinata, Vibrio alginolyticus, Anabaena flos aquae, Aeromonas spp., Lactobacillus spp and Plectonema boryanum UTEX 485 (Rajeshkumar et al., 2013; Mouxing et al., 2006; Brayner et al., 2007; Nair and Pradeep, 2002; Lengke et al., 2007). Researchers have produced AgNPs having 40 nm and 50 nm size, utilizing the Bacillus licheniformis (Kalishwaralal et al., 2008; Kalimuthu et al., 2008). Like plants, bacteria also possess the potentiality to stabilize metallic NPs. In numerous zones of the world, by utilizing Bacillus thuringiensis , gold, silver, cobalt, zinc, and copper NPs are produced and utilized against An. stephensi, the malarial vector, to control it (Wirth et al., 2010; Marimuthu et al., 2013).

Conclusions and insights for future research:

From the primitive ages, silver has been utilized enormously in medicine in various manifestations to rehabilitate a specific injury or malady. The silver together with other metals are utilized to synthesize NPs which fascinates tremendous attention today. In the domain of mosquito

management NPs exhibit a remarkable role to play. Malaria is a paramount persisting challenge against the scientists so far, together with various mosquito borne diseases. From this review it can be noticed that the silver nanoparticles are renowned as mosquito larvicidal agents against the malarial vector An. stephensi. However, more time is required to look into the genuine mode of action and any existing aftermaths of it.

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Conflict of interest

We have no conflict of interest

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