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Repellents and Toxicants for Personal Protection

Position Paper
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1. Introduction

Human beings are host to many species of biting insects, ticks, and mites. Through the ages, people have used a variety of techniques to protect themselves from arthropod bites and from infection with arthropod-borne disease agents. Among these techniques are included the use of physical barriers, such as clothing, screens, and nets; the use of chemical repellents on the skin and toxicants on nets, clothing, and other kinds of fabric; and the avoidance of areas infested with pests or disease vectors.

Modern day interest in the development of personal protection technology has been focused on chemical repellents and toxicants. In this regard, many repellents have been developed by borrowing materials or technology from other disciplines. Dimethyl phthlate, for example, was used as a plasticizer before its insect repellent properties were discovered (1). Formulation technology from the cosmetics industry was used to develop an extended duration formulation of deet (N,N-diethyl-3-methyl-benzamide) for use on human skin (2). And agricultural chemicals, such as pyrethroids, have been used to treat clothing and mosquito netting to protect against insect attack.

2. Target Taxa for Personal Protection

Seven families of biting flies in the Order Diptera are disease vectors and pests of humans worldwide (3,4). In the four Families of these flies classified in the Suborder Nematocera, only the females suck blood. Culicidae is the most important family and comprises the mosquitoes. These are generally grouped into daytime and night time feeders, although most species will bite at twilight (5). Females rely on odors, i.e., carbon dioxide, other breath components, and volatile skin products, as well as visual cues for host location

(6,7,8,9,10). Mosquitoes are major worldwide vectors of many disease agents, including those causing malaria, yellow fever, dengue, and filariasis. They may also be of significant nuisance, interfering with normal living, particularly outside the home. Sand flies (Psychodidae, Subfamily Phlebotominae) transmit *Leishmania* spp., which cause visceral, cutaneous, and mucocutaneous leishmaniasis in humans. Sand flies are active primarily at night and move via low hopping flights. They bite mainly on the face, ears and neck of persons sleeping/resting on or near the ground. Black flies (Simuliidae) feed in the daytime. In the tropical regions of Africa and America, *Simulium* spp. transmit *Onchocerca volvulus*, which is the world's second leading infectious cause of blindness in humans (11). Female black flies rely primarily on vision (12) for host location but are attracted by carbon dioxide, other kairomones (13), and heat. Biting midges (Ceratopogonidae) can serve as vectors for viruses, protozoa, and helminths (11,14), but may also be of great nuisance. Feeding is mainly diurnal and biting midges often attack in large numbers, inflicting numerous bites. Several species may feed on the same host simultaneously, with one species predominantly biting the arms, another species the legs, and yet another species biting the scalp (15).

Tabanids (Tabanidae), which are in the Suborder Brachycera, include horseflies and deerflies. Most tabanid species are active during daylight hours but favor bright, warm, overcast days (11,16). Only the females suck blood. They have broad, bladelike mouth parts that inflict a deep, painful wound, causing a considerable flow of blood, which they lap up by means of their sponging labella. Tabanids may feed on a succession of hosts and thus may be important in the mechanical transmission of pathogens (11,14).

Two important families of biting Diptera in which both the males and the females suck blood are classified in the Suborder Cyclorrhapha. Stable flies (Muscidae) feed during the daytime, at approximately daily intervals, and mainly on horses and cattle, although humans, dogs, and other animals can be attacked (17,18). Stable flies are persistent biters, even when interrupted while feeding, and, thus, can present a severe nuisance to humans (19); they are also mechanical vectors of protozoa and helminths in animals (14). Tsetse flies (Glossinidae), which occur only in tropical Africa, transmit the causative agents of African sleeping sickness (i.e., *Trypanosoma brucei rhodesiense* and *Trypanosoma brucei gambiense*) (11). Tsetse flies bite during the daytime and will readily attack humans and other large mammals. They feed every 2-3 days and are able to do so through heavy clothing (20,21,22).

Important biters among non-dipteran arthropods include kissing bugs, bedbugs, fleas, and lice. Kissing bugs (Order Hemiptera, Family Reduviidae) occur in North, Central, and South America and some species are important vectors of American trypanosomiasis or Chagas' disease (caused by *Trypanosoma cruzi*). Nymphal and adult kissing bugs feed during the nighttime and use host body warmth and carbon dioxide as attractants. In the daytime, these insects rest in tree hollows, under bark, beneath buildings, or in cracks and crevices in walls (23).

Bedbugs (Family Cimicidae) hide in crevices, mattresses, and bedsteads, during the day. Bedbugs are easily carried in clothing, traveling bags, and laundry and can be introduced with bedding and furniture. At night, they crawl from their hiding places and travel considerable distances to attack their victims (24).

Fleas (Order Siphonaptera, Family Pulicidae) have been associated with humans throughout history (25).

Xenopsylla cheopis, the oriental rat flea, and *Pulex irritans*, the human flea, are well known for their role in the transmission of the plague bacillus (*Yersinia pestis*) (11,19). Hungry fleas attack most kinds of warm-blooded animals where they move about freely on the host and bite different parts of the body.

Crab, body, and head lice (Order Anoplura) are obligate blood sucking ectoparasites on humans. They do not voluntarily leave a host but can be transferred from person to person by contact. Body lice are vectors of the disease agents that cause epidemic typhus, epidemic relapsing fever, and trench fever (26).

Mites (Order Acarina) in the Family Trombiculidae are distributed worldwide (27). The larvae, called chiggers, attack amphibians, reptiles, birds, and mammals. Chigger mites do not suck blood but feed on host tissue that has been digested with salivary enzymes. They attach to the body in a skin fold, a hair follicle, or between the clothing and skin.

Hard ticks (Order Acarina, Family Ixodidae) and soft ticks (Family Argasidae) are worldwide in distribution (28,29). They attack and suck blood from all vertebrates except fish and are important pests and vectors of disease agents in mammals. Soft ticks actively seek their hosts, usually at night, and feed for short periods. Hard ticks will climb to the tips of vegetation where they wait for a host to pass; vibration and other host stimuli activate questing behavior and allow the ticks to grasp onto animal fur or clothing. Hard ticks attach to the skin of the host and feed for several days to a week, or more, depending on the life stage.