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Electrostatic Strategies in Public Health: Current Uses and Future Innovations for Controlling Biological and Environmental Threat

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Abstract The following review aims to introduce electrostatic techniques for addressing public health issues caused by both living (biotic) and non-living (abiotic) agents. Biotic agents include viruses present in droplets, airborne fungal spores, pollen, and flying insect pests like mosquitoes and houseflies. The abiotic agent discussed is tobacco smoke. Electrostatic techniques involve creating electric fields between charged conductors, such as a metal rod, metal net, and spiked perforated metal plate, and a grounded metal net. These instruments generate two types of electric fields: static electric fields and dynamic electric fields. Static electric fields are utilized to capture or repel the target agents, while dynamic electric fields are employed to eliminate them through arc discharge exposure. Another application of dynamic electric fields is corona discharge generation, beneficial for trapping fine particles from tobacco smoke and viral particles carried by droplet transmission. This is achieved through the production of negative ions and ionic wind in the electric field. The electric fields produced serve as spatial barriers, preventing harmful agents from entering human living spaces by capturing, repelling, and killing them. Notably, the devices proposed in this review have a simple structure, enabling general readers to construct them inexpensively using common materials or modify them as needed. This review provides basic information and instructions on electrostatic techniques, serving as an introduction to new research in public health issues for readers who may not be familiar with technical aspects.

Keywords: *arc discharge, attractive force, corona discharge, electric field, negative ionization, spatial barrier*

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1. Introduction

Our primary focus is addressing public health challenges caused by both living organisms (biotic factors) and non-living factors (abiotic factors). Abiotic factors encompass issues like cigarette smoke and indoor air pollutants, while biotic factors include viruses, bacteria, fungal spores, and insect pests that carry these pathogens. This category also includes plant pollen. Among these factors, we prioritize tobacco smoke, cedar and cypress pollen, mosquitoes, and houseflies as the most critical targets due to their significant impact and the harm they cause.

Smoke is a complex mixture of gases and fine particles produced when organic materials burn. The most substantial health risk associated with smoke comes from these fine particles entering the eyes and respiratory system, leading to health issues such as eye irritation, a runny nose, bronchitis, as well as chronic heart and lung diseases, which are linked to premature death [1,2]. Passive smoking refers to the involuntary inhalation of environmental tobacco smoke by individuals who do not intend to smoke. Tobacco sidestream smoke permeates the surrounding environment and is inhaled by people within that environment. In fact, passive smoking can lead to many of the same diseases as direct smoking, including cardiovascular diseases, lung cancer, and respiratory diseases [3]. Pregnant women exposed to environmental tobacco smoke are at a heightened risk of delivering babies with congenital abnormalities, longer gestational periods, smaller head circumferences, and low birth weights [4]. Therefore, passive smoking stands out as one of the most significant indoor pollutants affecting human health.

Pollinosis is an allergic condition triggered by airborne pollen. In Japan, the primary culprits for pollinosis are pollen from Japanese cedar (*Cryptomeria japonica*) and Japanese cypress (*Chamaecyparis obtusa*). These allergens are prevalent across the country from February to May. Government research [5] indicates that more than 2.5 million people in Japan are sensitive to these pollen allergens. During the annual pollen season, they experience symptoms like headaches, eye congestion, itching, repeated sneezing with a runny nose, throat irritation, physical fatigue, and reduced concentration [6]. Typically, people ventilate their homes by opening windows. To enhance the quality of life for those suffering from pollinosis during the pollen season, we aimed to create pollen-free living spaces.

Mosquitoes serve as vectors for critical human diseases such as malaria [7], lymphatic filariasis [8], and certain viral illnesses like dengue [9], Japanese encephalitis [10], Zika [11], and yellow fever [12]. Effectively controlling these mosquito vectors has been a significant challenge in addressing public health concerns. The primary approach has relied on the use of chemical insecticides, mainly from the pyrethroid class [13], as well as mosquito bed nets [14]. The development of insecticide-treated mosquito nets [15] represents a physicochemical application of these two methods. However, the heavy reliance on chemicals has led to various issues, including the development of resistance in many mosquito species, environmental impacts, and health concerns for humans.

The presence of houseflies can lead to the transmission of harmful *Escherichia coli* O157, posing a potential threat to public health [16]. This strain of *E. coli* often causes food poisoning in individuals who consume fresh foods contaminated by the bacteria. *E. coli* O157 naturally reside in the intestines of cattle and sheep, where they do not cause any harm, but they can make their way into the human food chain through the feces of these animals. [16,17] Housefly larvae develop in animal feces, leading to the rapid buildup of large fly populations, especially on cattle farms and other agricultural facilities [18]. *E. coli* O157 ingested by houseflies can remain viable in fly excrement. As a result, houseflies can carry and spread this pathogen for several days [18]. Notably, this bacterial pathogen has been transferred from cattle manure used as a fertilizer for soil, leading to contamination of cultivated and harvested crops [19]. This contamination is a serious issue that can jeopardize the safety of the food supply chain [20-22]. It is crucial to substitute insecticides to control the emergence of houseflies from soil beds before they come into contact with crops in a greenhouse.

In this review article, we introduce a new trend in research aimed at effectively managing common public health issues using electrostatic techniques. We employ knowledge of electrostatics to create different electric fields, each with specific characteristics used to design devices capable of "capturing," "repelling," or "eliminating" these issues. The nature and shape of the conductor used significantly influence the properties of the resulting electric field, as it forms a space around the charged conductor.

The central idea introduced in this review is the use of electric fields to create a protective barrier, and the key proposition is that this barrier can be constructed inexpensively using readily available materials by general readers who don't possess any special expertise. Our approach to developing electrostatic devices is to start with a common, fundamental unit and then combine these units to create various applications, offering flexibility for different targets and settings. In fact, our review demonstrates the ingenious creation of a simple device capable of combatting not only the mentioned public health issues but also viruses transmitted through droplets.

Within this review, we provide basic information and explanations about electric field screens in a manner accessible to general readers who may not be familiar with technical details. The objective is to inspire their active participation in new research endeavors related to managing both living organisms and non-living environmental nuisances. Ongoing research in this field offers fresh insights for developing reliable methods and ensuring sustainable approaches that can adapt effectively to diverse environmental conditions.

2. Understanding Electrostatics in Innovative Devices

2.1. Charging Conductors with Voltage Boosters

To charge a conductor, such as a metal object, it is connected to a voltage booster linked to the ground. The voltage booster employs an increased voltage to facilitate the movement of electric charge. The direction of this charge movement is determined by the configuration of the Cockcroft circuit within the booster [23]. There are two main types of voltage boosters: one that imparts a negative charge to the conductor and another that imparts a positive charge [24]. The negative voltage booster draws negative charges from the ground and transfers them to the conductor, resulting in a negative charge on the conductor. Conversely, a positive voltage booster imparts a positive charge to the conductor by urging the free electrons within the conductor toward the ground.

2.2. Creation of Electric Fields

An electric field can be generated by combining an electrically charged conductor with a conductor connected to the ground. The negative charge applied to the conductor collects on its surface, forming an electric field in the surrounding space. An electric field is an area where the force exerted by negative charges is present [25]. When a grounded conductor is introduced into this space, the repulsive force produced by the negatively charged conductor pushes the negative charge (free electrons) of the grounded conductor into the ground, causing the grounded conductor to become positively charged. This phenomenon is known as electrostatic induction [26].

There are two main types of electric fields: static electric fields and dynamic electric fields [27]. In a static electric field, the negative charge given to a conductor remains stationary and does not move to the grounded conductor. When the charge of a charged conductor moves away from the conductor, it is called a discharge. From this perspective, a static electric field can be defined as a non-discharge electric field. Therefore, a dynamic electric field is an electric field in which discharging occurs.

A straightforward method to generate a static electric field involves insulating the charging conductor. Each insulating material has its unique volume resistivity, which, if the applied voltage falls within its allowable range, prevents the negative charge on the conductor's surface from dispersing. Conversely, the insulator used for the coating is influenced by the negative charge on the conductor's surface. It results in the outer surface of the insulator becoming negatively polarized, while the inner surface in contact with the charged conductor becomes positively polarized. This phenomenon is referred to as dielectric polarization [28]. Ultimately, the negative charge on the outer surface of the insulator, generated through dielectric polarization, positively charges the grounded conductor through electrostatic induction. A static electric field is established between these opposing electrodes. An electrostatic device that utilizes such a static electric field is known as an electric field screen [24].

Dynamic electric fields are simpler to create because they employ non-insulated conductors. The reason for not insulating the charged conductor is to facilitate its discharge. Two types of discharges are commonly used: Corona discharge and Arc discharge [27]. These discharges can be easily regulated by adjusting the applied voltage magnitude and the distance between the electrodes. Depending on the specific purpose, corona discharge and arc discharge electric fields are employed differently.

3. Creating Spatial Barriers Using Electric Fields

3.1. Single-charged Monopolar Electric field Barrier

To create an electric field barrier, a metal rod is employed as a conductor for electric charging. This metal rod is passed through a soft polyvinyl chloride tube to insulate it. An insulated metal rod is then connected to a negative voltage booster for negative charging. In this setup, an electrostatic field (monopolar electric field which cause no movement of the charge) forms concentrically in the space surrounding the insulated metal rod. By arranging multiple metal rods in this manner, ensuring the edges of each electric field touch, you can establish a space-shielding barrier with single-charged monopolar electric fields [24]. Initially designed to thwart fungal spores responsible for powdery mildew on cultivated tomatoes, this barrier prevents the spores, which are wind-borne, from passing through [29,30]. These multiple conductors are secured within a polypropylene frame and used as negatively or positively charged insulated rod units (rod-layer unit) (Figure 1A).

3.2. Double-charged Dipolar Electric Field Barrier

The second type of barrier consists of two-layer and three-layer variations [24]. The two-layer type combines a negatively charged and a positively charged rod-layer unit (Figure 2A). Conversely, the three-layer type comprises a single negative unit with a positive unit on either side (Figure 2B). In both types, each charged rod is positioned in an offset manner. An electric field is generated in the space between the opposing negatively charged and positively charged conductors (Figure 2C, D). This kind of barrier is created through double-charged dipolar electric fields. These barriers were originally devised to capture small flying insect pests [31,32].

3.3. Single-charged Dipolar Electric Field Barrier

The third barrier relies on single-charged dipolar electric fields (Figure 3A) formed in the space between the negatively charged rod-layer unit and a metal net unit grounded (fixed within a polypropylene frame) (Figure 3B). This barrier was designed to deter pests that have landed on the outer surface of the metal net. It capitalizes on the pests' inclination to avoid entering this electric field. [33].

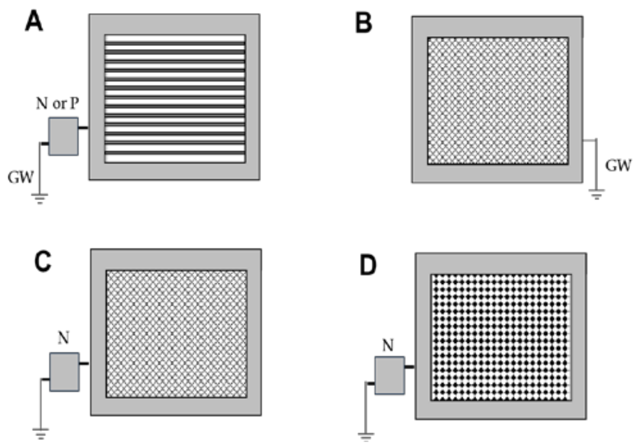

Figure 1. Units for constructing electric field screens. A: Metal-rod unit, consisting of a layer of insulated metal rods fixed within a frame and connected to a negative (N) or positive (P) voltage booster. B: Metal-net unit linked to a grounded wire (GW). C: Metal-net unit linked to a negative voltage booter. D: Perforated-metal-plate unit linked to a negative voltage booster

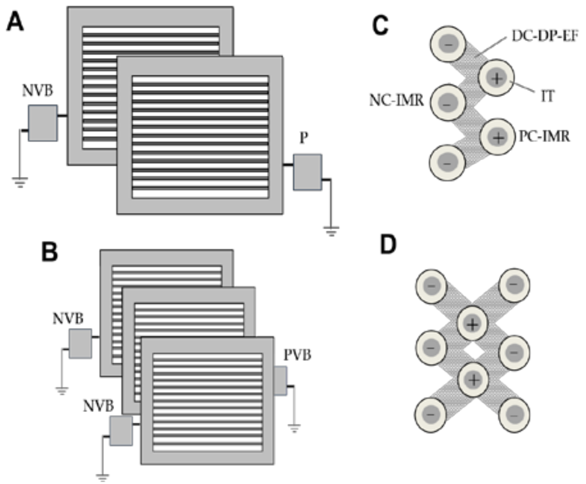

Figure 2. Double-charged dipolar electric field screens (A, B) by combining a negatively and positively charged rod-layer units and their electric fields formed between the negatively and positively charged insulated metal rods (C, D). Abbreviation: NC- and PC-MD, negatively and positively charged metal rods, respectively; IT, insulating tube; DC-DP-EF, double-charged dipolar electric field

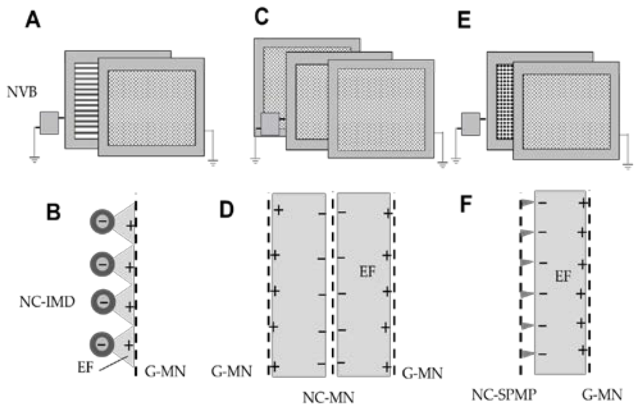

Figure 3. Different types of electric field screens and their electric fields formed. A, B: Single-charged dipolar electric field screen (A), in which an electric field (EF) was between the negatively charged insulated rod (NC-IMRs) and a grounded metal net (G-MN) (B). C, D: Arc discharge-generating screen (C), in which an electric field was formed between a negatively charged metal net (NC-MN) and a grounded metal net unit (D). E, F: Corona discharge-generating screen (E), in which an electric field was formed between a negatively charged spiked perforate metal plate (NC-SPMP) and a grounded metal net (F)

3.4. Arc discharge-generating Electric Field Barrier

The fourth barrier is constructed by combining a negatively charged metal net unit with a metal net unit connected to the ground (Figure 3C). An electric field is established in the space between these two units (Figure 3D). In the three-layer type, the grounded metal net unit is positioned on either side of the negatively charged metal net unit. Notably, the feature of this barrier is that the electrically charged metal net unit is not insulated. Consequently, pests that enter the electric field can encounter electric sparks from the charged metal net. These sparks are produced through the arc discharge of the charged metal net, rendering this the arc discharge-generation barrier designed to halt invading pests [27].

3.5. Corona Discharge-generating Electric Field Barrier

The fifth barrier incorporates a corona discharge generating electric field. This electric field is created by aligning a spiked perforated metal plate parallel to a metal net unit connected to the ground (Figure 3E, F). What sets this electric field apart is its ability to generate numerous negative ions around the tips of the charged spikes. When a target enters this electric field, these negative ions adhere to the target, imparting a negative charge. Simultaneously, the electric field generates an airflow, known as ionic wind [34], causing the negatively charged target to be carried by this airflow to the positive electrode (grounded metal net unit), where it is captured [27]. The grounded metal net unit used for the positive electrode can be substituted with grounded water [35].

4. Electrostatic Devices for Trapping, Repelling and Electrocuting Various Targets

4.1. Device for Capturing Tobacco Smoke Particles, Fungal Spores, Pollen Grains and Mosquitoes

A double-charged dipolar electric field screen (DD-screen) is an innovative electrostatic device designed to establish a protective spatial barrier capable of capturing a wide range of different targets as they enter the electric field. Specifically, the three-layer DD-screen (3L-DD-screen) (Figure 2B) boasts exceptional scavenging capabilities, effectively capturing fine particles found in cigarette smoke [36], airborne fungal spores [37], pollen [38], and airborne mosquitoes [32]. This capture mechanism for tobacco smoke particles, spores, and pollen is attributed to dielectrophoresis [39], a phenomenon that doesn't necessitate the target itself being electrically charged. For instance, when an insulated conductor is negatively charged, targets entering the electric field become polarized positively on the side facing the charged conductor and negatively on the opposite side. These polarized targets then follow the gradient of the electric field strength toward the negatively charged conductor, where they are captured. Similarly, if a positively charged conductor is employed, targets become polarized in the opposite manner but are still captured based on the same principle.

Small flying insects are trapped by charged insulated conductors of the 3L-DD-screen in a different manner. When an insect approaches a negatively charged insulated conductor, it experiences a repulsive force due to the conductor's negative charge, which causes the insect to release free electrons from its body. Consequently, the insects become positively charged and are subsequently attracted to negatively charged conductors, where they are captured [40]. This phenomenon is known as discharge-mediated positive electrification of insects. On the other hand, if an insect approaches a positively charged insulated conductor, it gains free electrons from the surrounding space near the charged conductor, causing it to become negatively charged and subsequently trapped by the positively charged conductor [40]. In both scenarios, the force exerted is powerful enough to prevent insects from escaping. Mosquitoes were effectively captured with the 3L-DD-screen [30].

4.2. Device for Repelling Adult Mosquitoes

A single-charged dipolar electric field screen (SD-screen) (Figure 3A) has been successfully used to deter pests, particularly adult mosquitoes, from entering buildings when attached to windows. The practical application of this screen was greatly enhanced by detailed observations of flying pests' behavior. It was noticed that when pests approached the SD-screen, they would typically land on the outer surface of the metal net, extend their antennae or legs inside, and appear to be inspecting the interior [41]. This behavior was consistently observed in all the insects we studied (17 orders, 42 families, 45 genera and 82 species) [42]. As a result, all these insects would fly away without actually entering the building, indicating their avoidance of the internal electric field generated by the SD-screen. This avoidance mechanism was especially effective in scaring away mosquitoes [42].

Another noteworthy feature of the SD-screen was its ability to effectively capture pests that managed to breach the internal electric field. The screen consists of a negatively charged insulated metal rod unit and a grounded metal net unit, creating an electric field between them (Figure 3B) [33]. When an insect entered this electric field, it lost free electrons due to the repelling force of the negative charge on the conductor, resulting in a positive charge and subsequent capture [43,44]. This phenomenon is similar to the discharge-mediated positive electrification observed in the DD-screen. In actual observations, there were rare instances where pests perched on the metal net of the SD-screen were pushed inside by the wind [41]. Even in such cases, the pests were securely trapped within the screen, preventing their escape. This pest-trapping function of the SD-screen further increased its practical value for pest control.

4.3. Device for Zapping Adult Mosquitoes and Houseflies

An arc discharge-generating electric field screen (ADG-screen) (Figure 3C) comprises three metal net units. The central unit is negatively charged (Figure 1C), creating an electric field for sparking in the space between the units on both sides (Figure 3D) [27]. The primary advantage of this design is safety. Although high voltages are applied to the central unit, the grounded metal meshes on both sides prevent users from touching the charged metal net and getting an electric shock. In fact, ADG-screens are installed on windows to keep mosquitoes out [45], and even if users touch the exterior of the grounded metal net, there's no danger.

Whether sparking occurs between the charged and grounded units depends on the applied voltage and the gap between them. For the ADG-screen, the minimum distance that doesn't cause sparking between these two units is defined for each voltage used. With such a screen, only when a pest enters the electric field between the units does a spark discharge toward the pest [45]. Since most pests have a conductive outer layer, they become intermediate electrodes, receiving a charge from the charged conductor, which is then directed to the grounded unit through a two-step sparking process. Whenever a pest enters between the units, it gets electrocuted by this spark exposure [45].

In the case of houseflies emerging from underground pupae, a two-layered ADG-screen was used as a soil cover to eliminate houseflies on the soil surface [46]. In this situation, it was crucial to consider the possibility of accidental human contact with the charged unit, as it remains exposed. The mentioned voltage booster was of the continuous-charging type with a high output for charging, but there was always a risk of an electric shock when inadvertently touching the charged metal net unit. To ensure the ADG-screen's safety, a pulse-charging type voltage booster was employed. This type of booster has been previously used to electrify electric pasture fences for deterring wild animals, and it posed no safety issues during usage [47]. Since this voltage booster was operated by a solar panel-powered battery, it offered the advantage of being usable without the need for special electrical wiring and remained unaffected by outdoor weather changes [46].

4.4. Device for Generating Corona Discharge to Precipitate Tobacco Smoke Particles and Virus-Containing Droplets

In the corona discharge-generating electric field screen (CDG-screen) (Figure 3E), a perforated metal plate with spikes attached to a designated frame (Figure 1C) functions as a negatively charged conductor. This plate is combined with a metal net unit connected to the ground. The electric field created by the CDG-screen (Figure 3F) is characterized by the production of numerous negative ions around the negatively charged spikes and the generation of an ionic wind from the negatively charged unit towards the grounded metal net unit, which acts as the opposite electrode. This ionic wind also draws in the surrounding air into the electric field. If cigarette smoke is present in the surrounding air, it is pulled into the CDG-screen. The fine particles in cigarette smoke interact with the negative ions in the electric field, becoming negatively charged [46]. These negatively charged particles are then transported to the metal net unit, where they are captured. In practical terms, if the CDG-screen is operated in a room filled with cigarette smoke, the smoke can be removed from the air relatively quickly.

An alternative CDG-screen configuration replaces the grounded metal net unit with a water-trap [35]. In this case, the grounded metal wire is submerged in water, effectively grounding the water itself. This setup allows the negatively charged particles to be trapped in the water. This method has been employed for capturing virus particles transmitted by droplets. In experiments, Escherichia coli bacteriophage was used as a model virus, sprayed into the air, and then recovered in the water-trap of the CDG-screen (grounded water-trapping type) for quantification. Since it was demonstrated that the negative ions produced by the CDG-screen can adhere to atomized water droplets and be captured at the grounded water electrode, it is expected that this method could effectively remove viruses, such as the new coronavirus, which are transmitted by droplets in enclosed spaces [35].

5. Future Research Directions

5.1. Exploring the Connection Between Volume Resistivity of Insulators and Their Performance

Electric field-based pest control devices are divided into two categories based on whether they use an insulated conductor for charging purposes. Insulation of the charged conductor is essential for creating devices that can capture and repel insects. In laboratory experiments, an insulated conductor wire is typically achieved by passing a metal wire through a soft polyvinyl chloride tube. The volume resistivity of polyvinyl chloride is typically around 1015 Ωcm, but it can be reduced to a range of 1014 to 108 Ωcm by adding plasticizers or ultraviolet absorbents to improve weather resistance. There are various soft polyvinyl chloride materials available on the market, each blended with different substances, each having distinct properties and varying volume resistivities. Previous devices have successfully used a conductor covered with a soft polyvinyl chloride tube with a resistivity of 1.5×109 Ωcm [44]. In future research, it is essential to explore the relationship between the volume resistivity of insulating materials and their performance.

5.2. Investigating the Mortality of Mosquitoes and Houseflies Captured Using the DD-Screen

Matsuda et al. [48] have reported that houseflies placed within an electric field generated by a negatively charged insulated metal plate and an uncoated metal plate grounded become deprived of free electrons and get trapped by the charged insulated metal plate, ultimately resulting in their death within a matter of minutes to tens of minutes. Conversely, in an electric field surrounding the positive electrode of the DD-screen, pests gain access to free electrons and get trapped at the positive electrode [40]. If pests captured at the positive pole also meet a similar fate, the DD-screen could prove to be a more effective trap-and-kill solution. The initial challenge at hand is to determine whether both houseflies and mosquitoes will succumb to this method. This approach holds promise as an environmentally friendly pest control method that doesn't rely on insecticides.

5.3. Investigating the Perceived Limits of Field Strength in a Static Electric Field Using Mosquitoes and Houseflies

Newland et al. [49] reported that cockroaches have the ability to detect electric fields through their antennae. When exposed to an electric field, cockroaches respond by deflecting their antennae towards the source of attraction, caused by an uneven charge distribution on the cockroach, with negatively charged parts being drawn towards a positively charged electrode [49]. Recently, Matsuda et al. [50] examined how cockroaches navigate within a static electric field created by the SD-screen and concluded that cockroaches sense an attractive force acting on their antennae when introduced to this electric field. This attraction is due to the removal of electrons from the antennae, causing them to become positively charged and drawn towards the oppositely charged insulated metal wire [50]. As a result, the insects instinctively retract their antennae and move away. These findings indicate that cockroaches can detect a force within the electric field when their antennae enter it, even if they may not recognize the static electric field itself. The strength of the electric field generated is directly proportional to the applied voltage. Previous research [42] examined 82 species of insects, including arachnids, and found variations in their ability to perceive static electric fields based on the minimum recognizable voltages. In the future, it is crucial to determine the minimum field strength of the static electric field that mosquitoes and houseflies can detect. This information serves as a fundamental foundation for understanding how these insects perceive static electric fields. In theory, a static electric field can be generated not only using the SD-screen but also the ADG-screen. The ADG-screen is typically employed to create dynamic electric fields that lead to discharges. However, by reducing the applied voltage, it is possible to create an electric field that does not produce discharges, essentially making it static. If mosquitoes and houseflies are capable of repelling the static electric field created by the ADG-screen, it could expand the practical applications of this technology, making it more cost-effective and easier to implement, as it would not require insulating conductors to carry a charge.

5.4. Examining the Versatility of the SDG Screen

An intriguing question arises regarding the capability of the CDG screen to capture bacteria, spores, pollen, and small pests. The underlying mechanism of this screen involves charging incoming targets with negative ions generated within an electric field and trapping them at the opposing electrode [51]. In theory, this screen should be capable of capturing any target. However, the key challenge lies in the size of the target allowed to enter the screen's electric field. This screen establishes an electric field between the spiked perforated metal plate and the grounded metal net (Figure 3F). To initiate corona discharge, it is essential to determine the optimal electrode distance for the applied voltage. Given that the distance between the electrodes is 9 mm [51], there should be no issue in accommodating bacteria, spores, and pollen, in terms of their size. Furthermore, small pests, including mites, can be easily captured, provided they are small enough to pass through a typical insect repellent net with a mesh size of approximately 1.5 mm. Of particular importance is the potential to capture house-dust mites, as they are known to be causal agents of allergic asthma in humans [52]. Therefore, capturing them could prove to be a significant approach in enhancing public health conditions.

6. Conclusion

This review paper aims to provide general readers with a basic understanding of electrostatic science, including the creation of electric fields, the concept of space-shielding barriers constructed using electric fields, the use of various devices that incorporate these barriers, and the identification of areas requiring further research. Throughout this writing, we have kept in mind that our audience may not possess specialized skills in constructing electrostatic equipment, and we have strived to ensure that anyone can create the necessary equipment without encountering any difficulties. To facilitate this, we have proposed three fundamental units that are easy to produce and designed them in such a way that they can be assembled simply by combining these units as needed. We hope that this approach will inspire many readers to explore new electrostatic techniques introduced in this paper and foster a fresh wave of research efforts aimed at addressing factors contributing to public health issues.

In previous research, various aspects of electric fields have been introduced; however, these represent just a fraction of the vast realm of electric fields. If numerous researchers embark on new challenges, it is possible that previously unnoticed facts may come to light, eventually leading to fresh insights for managing factors that seriously impact public health. This review serves as a starting point for uncovering new research avenues in pursuit of this goal.

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