Commentary

Sustainable Pest Management for Health and Well-Being

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Pests can not only cause nuisances and allergic reactions and transmit a range of diseases, but they can also pose serious threat to other aspects of life such as the environment, food, agriculture, crops, etc. Over time, the pest control industry has made great progress but has encountered some new challenges and gaps.

To adapt to global changes effectively, pest management strategies are changing constantly. The concept has transitioned from integrated pest management (IPM) to sustainable pest management (SPM) to provide the optimal solution. China, as the world's largest developing country, has continuously contributed innovative ideas to the pest management industry to promote sustainable development of pest management globally. This paper focuses on pests and their adverse impacts, especially in the health field, the challenges and gaps in pest management, the conceptual transition in pest management, and future perspectives.

Pests and Their Adverse Impacts

Pests are organisms that damage human life, production, and even survival. They can cause significant losses in lives and property and also great loss in other fields such as agriculture, food, environment, and ultimately have a negative impact on people's health and well-being. Pests can be roughly divided into seven categories based on their adverse impacts (Table 1).

On the basis of the World Health Organization's (WHO) report, 80% of the world's population is at risk of one or more vector-borne diseases (VBDs), and 17% of the global burden of communicable diseases and over 700,000 deaths are due to VBDs. Malaria causes an estimated 219 million cases globally and results in more than 400,000 deaths every year. More than 3.9 billion people in over 129 countries are at risk of contracting dengue with an estimated 40,000 deaths every year. More over, there are other VBDs including mosquito-borne diseases such as Chikungunya fever, Zika virus infection, yellow fever, West Nile fever, and Japanese encephalitis as well as tick-borne encephalitis. Of note, some VBDs such as Chagas disease (transmitted by triatomine bugs), leishmaniasis (sandflies) and schistosomiasis (snails) affect hundreds of millions of people worldwide.

In China, vectors transmit 10 notifiable VBDs in 3 categories [category A: plague; category B: hemorrhagic fever with renal syndrome (HFRS), epidemic encephalitis B, dengue, leptospirosis, schistosomiasis, and malaria; and category C: epidemic and endemic typhus, visceral leishmaniasis (kala-azar), and filariasis], 10 non-notifiable and common VBDs (tick-borne forest encephalitis), Xinjiang hemorrhagic fever, Lyme disease, bartonellosis, Zika virus infection, human ehrlichiosis, anaplasmosis, Tsutsugamushi disease, Chikungunya, severe fever with thrombocytopenia syndrome (SFTS), and many other kinds of NTDs or emerging VBDs.

For the adverse impacts of pests in other fields, the Food and Agriculture Organization of the United Nations (FAO) reports that up to 40% of food crops are destroyed by plant diseases and pests every year. This has resulted in food shortages for millions of people and has caused negative impacts on the main sources of income for poor rural communities by resulting in production and trade losses. In recent years, China's grain production has been reduced by about 40 million tons annually due to pests, which can supply the annual grain consumption of about 80 million people or about 5.3% of China's total population.

Pest can also cause serious losses in animal husbandry. Through biting, *Tabanus* horseflies can directly reduce the body weight of cattle by 0.1–1 kg per day and lead to the reductions in production resulting in huge economic losses. Ticks can spread babesiosis, and theileriosis (East Coast feeder) among livestock causing significant economic losses. In 1999, the animal husbandry losses caused by ticks in Tanzania reached 55 million US dollars.

Based on the FAO's report in 2010, nearly 40 million hectares of forest were affected by plant diseases and insect pests every year. In recent years, the annual average occurrence area of forest pests in China is 120 thousand square kilometers, and the annual

TABLE 1. Pests and their adverse effects.

No	Category of pest	Representative species	Adverse effects	Sources
1	Disease vectors	Mosquitoes, sandflies, triatomine bugs, ticks, fleas, flies (various species), aquatic snails, lice, mites, midges, rodent, etc.	· Globally: · 80% of the world's population is at risk of one or more vector-borne diseases (VBDs). · 17% of the global burden of communicable diseases is due to VBDs. · Over 700,000 deaths are caused by VBDs annually. · China: · 10 notifiable VBDs, 10 non-notifiable and common VBDs, and several other kinds of other NTDs or emerging VBDs. · In 2019, 13 indigenous dengue transmission provincial-level administrative divisions (PLADs), and more than 0.9 billion people are at the risk of dengue. · Imported malaria from Africa and Southeast Asia pose a challenge to the elimination of malaria in China by 2020. · Adult epidemic encephalitis B outbreak in the provinces of Northwest China in recent years.	[1] Global vector control response (GVCR) 2017–2030. [2] Qiyong Liu, 2020.
2	Exotic invasive pests	*Solenopsis invicta* Buren, *Bursaphelenchus xylophilus*, ragweed, water hyacinth, etc.	· *Solenopsis invicta* Buren: · Globally: · One of the 100 most destructive invasive pests in the world, this pest poses a great threat to biodiversity protection and agricultural production. · As of 2012, more than 100 million acres of land in 12 south states of the United States had been infested, with an estimated annual economic loss of more than 5 billion USD and over $750 million in agricultural losses. · China: · In 2013, detected in 169 counties (cities and districts) of 7 PLADs. · Bursaphelenchus xylophilus: · Globally: · Occurs in Japan, Republic of Korea, the United States, Canada, Mexico, Portugal, China, and other countries and causes significant loss. · China: · After an invasion to Hong Kong in the 1980s, the *Pinus massoniana* was almost destroyed by this pest. · The economic losses caused by *Bursaphelenchus xylophilus* disease in Anhui and Zhejiang provinces are up to 70.18–98.26 million USD.	[1] http://blog.sciencenet.cn/blog-990233-763021.html [2] https://baike.baidu.com
3	Architecture and building material pests	Termites, wood-boring beetles, *Monochamus*, *Sinoxylon*, *Lyctus*, *Trogoderma*, etc.	· Termites: · Globally: · More than 3,000 species in the world and known as "silent destroyers" because of their ability to chew through wood, flooring, and even wallpaper undetected. · The direct economic loss caused by termites reach up to tens of billions USD every year. · China: · More than 70 species that can damage architecture and housing materials. · The economic loss caused by termites to housing construction is close to $1.0 billion every year.	[1] https://www.pestworld.org/pest-guide/termites/ [2] https://baike.baidu.com

TABLE 1. (Continued)

No	Category of pest	Representative species	Adverse effects	Sources
4	Warehouse pests	Flour beetles, grain borers, corn weevil, rice weevil, corn beetle, wheat moth, *Tribolium castaneum*, etc.	· Globally: · More than 300 species, causing direct weight loss, quality loss and mildew. · China: · More than 50 species, causing about 8%–10% of the total reserves in grain, beans and oil-bearing crops by warehouse pests. · Corn weevil ranking first in warehouse pests in China.	[1] Jianguo Xu, 2018 [2] https://baike.baidu.com
5	Textile pests	Carpet beetles, moth, etc.	· Globally and China: · Causing huge losses in the production and storage of commercial fabrics and clothing.	[1] https://wenku.baidu.com/view/8d869511cbaedd3383c4bb4cf7ec4afe04a1b122.html [2] https://www.byepest.com/pest_wiki_details/13
6	Agricultural and forestry pests	Locusts, aphids, etc.	· Globally: · Agricultural pests: · Up to 40% of food crops destroyed by plant diseases and pests every year. · Locusts: · About 300 species are harmful to agriculture, forestry, and animal husbandry. · The annual area of locust disasters amounting 46.8 million square kilometers, and one eighth of the world's population is affected by locust disasters. · The most serious locust is *Schistocerca grigaria*, with a maximum diffusion area of 28 million square kilometers, including whole territories and partial areas of 66 countries, accounting for about 20% of the world's land area and more than 10% of the world's population. · Aphiods · One of the most destructive pests on earth. · About 250 species harmful to agriculture, forestry and horticulture. · Forest pests: · The area of forest affected by pests every year reaching 34 million hectares, accounting for 1.6% of the forest area of 94 reporting countries. · China: · Agricultural pest: · Locusts: · The severest locust disaster in a year in China causing nearly 0.20 million square kilometers crop loss, with an average of 0.10 million square kilometers and an average annual loss of 0.25 billion USD, posing a serious threat to food production and ecological security of grassland areas. · In 2008, Heilongjiang suffered from *Loxostege stieticatis* damage, with a disaster area of more than 2.867 million hectares. · In 2004, Jiangxi suffered rice diseases and insect pests, with a total loss of 1.7 billion kg of grain. · Forest pests · The annual average occurrence area of forest pests in China amounted to 120 thousand square kilometers, and the annual average economic loss reached 15.46 billion USD.	[1] FAO, 2010 [2] National Forestry and Grassland Administration (NFGA), China, 2019 [3] https://baike.baidu.com [4] Jianguo Xu, 2018
7	Animal husbandry pests	Ticks, tabanus, etc.	· Globally: · Tick-borne diseases (TBD) constraining cattle production and improvement in Tanzania, and the total annual national loss due TBD estimated to be 364 million USD, including an estimated mortality of 1.3 million cattle.	[1] Fredrick M Kivaria, 2006 [2] Busin V, 2018

average economic loss is 15.45 billion USD.

Challenges and Gaps Towards Pest Management

In recent years, climate and environmental change, globalization, urbanization, insecticide resistance, human behavior change, etc., pose new challenges for pest management causing unfavorable effects to the health and well-being of humans.

Changes in vector distribution are being driven by climatic and environmental changes. Globally, the areas and human populations at risk for dengue have recently been increasing significantly due to the spreading of *Aedes albopictus* and *Ae. aegypti* resulting from climate change. In China, more than 0.9 billion people currently reside in the risk area of dengue (*1*), and the risk area and risk populations will increase significantly in the future (*2*). Due to climate change, mosquitoes in *Culex pipiens* complex have established its population in Lhasa, Tibet (*3*). With the changing of the environment, human granulocytic anaplasmosis, a tick-borne disease, was identified in China before 2006 (*4*). In 2019, the market scale of China's health insecticides reached more than 2.10 billion USD and will continue to grow at a rate of more than 8%. In the future, insecticide resistance will become a more and more serious problem. Outside of China, an unprecedented change in the status of VBDs in Europe has occurred in the early 21st century due to increased globalization (*5*).

In addition, there are still many deficiencies and gaps concerning capacity building such as insufficient ability for the fast identification of pests, lack of high-tech pest surveillance and control tools, lack of self-protection awareness against pests, etc.

Transition of Pest Control Strategy: from IPM to SPM

IPM is a science-based, strategic approach for managing insects, rodents, or other vectors. It uses a variety of pest management techniques that focus on pest prevention, pest reduction (*6*), and the elimination of conditions that lead to pest infestations. Integrated vector management (IVM) is a key component of IPM (*7*). Though IPM is a comprehensive approach to pest management, its noticeable deficiencies are its lack of planning and systematization towards pest management, more involvement in the technicalities of the method, and being time and energy consuming. Therefore, an innovative pest management concept is urgently needed to guide the pest management practice.

SPM was first proposed by Professor Qiyong Liu in the Pest Management Industry Global Summit, which took place on May 25–27, in Barcelona, Spain in 2010. SPM is designed to meet society's current and future needs for the protection of human health and the environment for the production of food, feed, and fiber and for the use of natural resources. SPM stresses on systematic and sustainable pest management through pest surveillance, risk assessment and alert, control planning, good pest control practice, monitoring and evaluation. It combines a range of pest management practices, including judicious use of pesticides to ensure that our natural resources are utilized efficiently and conserved for future generations. It also addresses the economic viability of available and new pest control products and practices and the planning and systematic nature of pest management. In recent years, VBDs posed great challenges to existing vector control strategies and measures, and mitigation of VBDs will increase economic prosperity by reducing poverty, decreasing productivity losses due to death and disability, and reducing inequality in health and economic outcomes.

Take *Aedes* control for dengue management in China for example. The process of dengue control under the guidance of SPM (with SVM as the core) is as follows (*8*): first, carry out *Aedes* surveillance in a timely and effective fashion; second, conduct a feasibility risk assessment and control planning of *Aedes* and dengue; and third, choose environmentally friendly techniques and measures comprehensively and in order to implement surveillance-based *Aedes* control and management consistently. During the process, conduct coordinated activities with multisectoral collaboration and public participation, and suppress the *Aedes* density below the threshold of dengue transmission (Breteau index or Mos-ovitrap index<5) (*9*). This method promoted the transition from reactive outbreak response to proactive outbreak risk reduction of *Aedes*-borne diseases in China.

As a core component of SPM, SVM was cited by the "Guidelines for dengue prevention and control (2014)" from the China CDC and "Western Pacific Regional Action Plan for Dengue Prevention and Control (2016)" from the WHO. Other WHO guidelines also reference SVM including "The global strategy for dengue prevention and control (2012–2020)" and "Global Vector Control Response 2017–2030" (*10*), etc.

SPM for Health and Well-Being

In the future, we will confront challenges and gaps continuously, and some new challenges may also emerge (*11*). Pests will become increasingly harmful and will adversely affect public health and well-being. Therefore, current challenges need to be addressed, existing deficiencies must be made up, and SPM should be carried out. Global and regional cooperation, multisectoral joint action and multi-disciplinary integration should be strengthened, and the participation of the whole society should be advocated to actualize the sustainable control of pests and the promotion human health and well-being.

In the long run, SPM is likely to be beneficial for the reduction of diseases and poverty, protection of the environment, elimination of hunger, promotion of economic development, and ultimately contributing to human health and well-being and the achievement of sustainable development goals (SDGs).

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