Current situation of pesticide residues and their impact on exports in China

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Abstract. Pesticide residues not only endanger human health and lead to concerns about food safety problems, but also seriously affect the export trade of agricultural products. Therefore, pesticide residues have become an important issue in the field of food safety in China and a primarily concern in Chinese society. In the past 11 years, RASFF has summarized and analyzed the information of pesticide residues in exported food in China, and clarified the risk of agricultural pesticide residues in our country. Using stakeholder theory to analyze the demand and perception of eight different stakeholders, this paper puts forward policy suggestions for reducing pesticide residues in China's main agricultural products.

1. Introduction
Pesticide residues have always been an important concern globally in agricultural safety [1], and China is no exception. China has 10% of the total arable land in the world, but needs to support over 20% of the global population [2]. Pesticides have undoubtedly helped to increase agricultural production and control disease vectors [3]. Pesticides have played an irreplaceable role in improving agricultural output from China during the last decades, and China has become the largest pesticide producer and exporter in the world [4] The average annual use in China is about 1.8 million tons, and pesticides are widely used in agricultural production to prevent or control pests, diseases, other plant pathogens, and weeds in an effort to reduce or eliminate yield losses and maintain high product quality [5]. But the use of a large number of pesticides has led to excessive, unreasonable, or even abusive use of pesticides, causing negative effects to human health, ecosystems, and foreign trade. In 1992, the World Health organization (WHO) reported that roughly three million pesticide poisonings occur in humans annually, resulting in 220,000 deaths worldwide [6].

1.1. Selected countries or organization of pesticide residue legislation
Pesticide legislation varies greatly worldwide, because countries have different requirements, guidelines, and legal limits for agricultural production. Compared to developing countries, which lack the resources and expertise to adequately implement and enforce legislation, developed nations typically have more stringent regulations (Table 1) [7]. The differences in regulations matter and might, in some cases, hinder trade [8]. Most countries use Maximum Residue Limits (MRLs) to regulate pesticides. Maximum Residue Limits are defined as “the upper legal levels of a concentration for pesticide residues (expressed in mg/kg) in or on food or feed based on Good Agricultural Practices (GAP) and to ensure the lowest possible consumer exposure”[9].

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The EU pesticide legislative framework has evolved considerably over the years. Until 2009, the EU published four pieces of legislation which make up the “thematic strategy for pesticides [10]. The last major revision of the law regulating plant protection products in the European Union (EU) was mainly enacted through the introduction of the current Regulation (EC) No. 1107/2009, which entered into force on 14 June 2011[11]. As to the pesticide residue, since 1993 the EU has been implementing a programme to establish harmonised Maximum Residue Levels (MRLs) for pesticide residues in foodstuffs sold in the EU, till 2000, the EU has been aiming to establish MRLs for 102 pesticide active ingredients [12].

In 2013, the Pesticide Registration Improvement Act was re-established. In this process, the formulation or revoked in food and feed pesticide maximum residue limits of the work. In order to ensure food safety and consumer interests, the United States developed a standard MRL system with evaluation standards. This system included 380 kinds of pesticides and had 11,000 items including time limits or temporary imports. This MRL system put forward the concept of "zero residual" and "risk cup " principle [13]. Through constant revision and continuous legislation, the United States has established the most comprehensive system of pesticide registration and pesticide residue supervision in the world [14].

In Japan, the system established by the “Positive List” is considered to be the most stringent test standard in the world, and is in line with the standards of countries such as Europe and the United States. This system provides a maximum guarantee of domestic food safety. Rules defined in the Positive List System for agricultural chemicals (pesticides, veterinary drugs, food additives, etc.) were very strict, and included pesticides and pesticide residue limits the number of 579 species and more than 51600, accounts for more than 70% and 90% of the total [15].

As the largest producer and user of pesticides in the world, pesticide use and control have become a significant issue in China. China's MRLs for pesticides take national and industry standards into account. National standards are issued by the Ministry of Health and the National Standardization Management Committee, while the industry standards are issued by the Ministry of Agriculture (MOA). In 1963, the Institute for the Control of Agrochemicals (ICAMA) MRL was established in MOA, and was responsible for pesticide registration and management [7]. But it was not until June 1, 2009, that China implemented the Food Safety Law, which was coupled with a series of other announcements and programs issued by the MOA. With the Food Safety Law, China created a way to enforce a standard system for reducing pesticide residues. However, there are some shortcomings and gaps in pesticide regulation in China compared with international pesticide residue standards. First, the number of pesticides being regulated is insufficient. At the end of 2015, China's total pesticide residue limit included 3650 projects, far less than the standard number in developed countries: the United States has more than 10,000, Japan has more than 50,000, and the EU has 145,000. Second, the accuracy and scientific need to be improved. In China, pesticide residue limit standards were not established early on and basic toxicological test data was lacking. Because of this, scientific risk assessment of MRLs needs to improve. Third, there is a lack of systematic detection methods throughout China. For example, some methods used to detect pesticide residues conflict because there

### Table 1. Comparison of agricultural residue limits between China and Western Developed Countries or Organizations.

| Country/Organization | Pesticide species | Numbers of Pesticide Residue Limit Standards |
|----------------------|------------------|---------------------------------------------|
| The European Union   | 470              | 145000                                      |
| The United States    | 381              | 11000                                       |
| Japan                | 579              | 51600                                       |
| China                | 387              | 3650                                        |
are national standards, industry standards, and local standards that are not the same. Fourth, exemption limits and limited standards are still lacking. The United States, Japan, and the EU have developed a total of 146 species, 65 species, and 53 kinds of exemption substances, all the remaining limit of the amount of pesticide, such as amines. There are also specific lists, but China has not been involved in terms of exemption and limited standards.

1.2. The main hazards and effects of pesticide residues
Agricultural safety and the resulting environmental and health problems from pesticide application are increasingly attracting global attention [16]. In general, the main hazards include at least three aspects: field workers may be poisoned by spraying chemicals, sometimes fatally; the environment may be polluted, to the detriment of many living things within it; and food can be contaminated with occasionally lethal consequences in human consumers [17]. In some cases, common adverse reactions, such as headaches and vomiting, may be related to pesticide residues in diseases such as cancer and neurological disorders [18].

1.2.1. Endangering human health Pesticide use is important in agriculture to protect crops and improve productivity. However, pesticides have the potential to cause adverse human health effects [7]. Higher pesticide residues can cause very serious damage to human health. Intake of residual pesticides, after long-term accumulation, may induce gene mutations, increase the incidence of deformity and increases the possibility and proportion of cancer. In addition, research has shown that exposure to OPs exposure affects headaches, allergies and nausea, physiology, and increases the frequency of cancer, and neurological disease [19].

1.2.2. Pollution of soil, water and air When pesticides are sprayed in China, the majority are lost to the ground and the air; around 20%-40% of the pesticides sprayed spread to the air, while about 40%-60% of the pesticides land on the ground. Free, airborne pesticides penetrate the soil through precipitation or enter the water, causing soil, water, and air pollution. Pesticides remaining in the soil can reduce the number of beneficial soil microorganisms and some of the residual pesticides that are not degraded are absorbed into the food through plants roots and adversely affect human health through the food chain. Pesticide residues in the water, can reduce the number of fish and other aquatic organisms, which degrades aquatic ecosystems. Pesticide residues in the atmosphere, can be absorbed by the body, and enter into the blood circulation, directly harming human health.

1.2.3. Impacts of pesticides on agricultural exports The results of research by Wilson and Otsuki (2004) on the banana import and export trade showed that pesticide residue limits have a large impact on international trade for developing countries that rely on agricultural trade. The EU, Japan, the United States and other countries or organizations have more stringent standards for agricultural pesticide residues, which directly impacts developing countries, often resulting in huge trade losses for agricultural exports. Japan, as the largest exporter of agricultural products of China, has the world's most stringent standards for pesticide residues. In 2002, Japan raised the standard of imported spinach pesticide residues, which directly led to a loss of US $3 million from Chinese export enterprises in Shandong. Since the "Positive List System" was implemented in Japan, many provinces and cities in China have suffered serious impacts to agricultural exports due to pesticide residues. From 2006 to 2009, China's average annual loss of agricultural products exports due to excessive pesticide residues increased up to US $7 billion. In a case study of onion exports to Japan in 2014, 400,000 tons of fresh or frozen onion were exported with a value of $174 million [15].
2. Status and causes of pesticide residues in China

2.1. Status of pesticide residues in China

The overall rate of excessive pesticide residues from agriculture in China is around 5%, mainly in fruits and vegetables, which is far higher than in other developed countries. In 1998, the rates of excessive pesticide residues of domestic fruits and vegetables were 1.4% and 0.9% respectively, while imports were 3.6% and 2.9% respectively. In 1996, the rate of excessive pesticide residues of fruits and vegetables in the Netherlands was about 1.4%. However, also in 1996 the rate of excessive pesticide residues in Chinese fruits and vegetables was about 10%. In 2005, tests on supermarkets and farmers’ markets in six counties of Shan’xi province showed that the rate of organophosphate pesticide was 27.4%, an increase of 9% from 2004. In recent years, due to pest resistance and changes in pesticide markets, mixed pesticides were widely used, such as binary pesticide mixtures [18].

2.2. Cause of excessive pesticide residues in China

2.2.1. Misuse is a direct cause of excessive pesticide residues

China consumes 1.8 million tons of pesticides annually, making China the world’s largest pesticide user. Chinese farmers sprayed 14 kg/ha of pesticides annually, which is several-fold higher than the amounts applied in the USA (2.2 kg/ha) and France (2.9 kg/ha) [20]. Since 1996, pesticide use in China has been growing rapidly, with pesticide use in 2010 1.54 times higher than 1996. Since 2010, the pace of growth has slowed, and has remained largely flat, but the total amount of pesticides in the country remains above 1.8 million tons (Figure 1). In addition, consistent with large amounts of pesticide use, abuse of pesticides has exacerbated residues in China. In China, only 10% and 20% of powder and liquid pesticides, respectively, remain on crops when they are sprayed. The rest of the pesticides end up in the air or on the ground.

![Figure 1. The annual use of pesticides in China (unit: 10000 ton).](image1)

![Figure 2. Notifications due to excessive pesticide residues in China since 2006 in RASFF.](image2)

2.2.2. Lack of technology contributes to excessive pesticide residues

The technology and ability to detect pesticide residues in China lag behind other countries. For example, pesticide residues in Chinese vegetables are normally under 1.0 mg/kg, but according to the rapid detection of pesticide residues "GB/T5009.199-2003" method, the detection limits rarely reach 1.0 mg/kg. Thus, this method is not useful and will worsen the problem of pesticide residues on vegetables. In addition, farmers in China lack training related to pesticide use, and the majority of Chinese farmers have not had specialized, technical training for using pesticides. Based on a survey of 307 farmers from the Wei River basin, pesticide overuse is driven by limited knowledge and low awareness of pesticide risks [21]. The frequency of use, concentration, and the choice of optimum control period for pesticides, mainly relies on the farmer’s experience and judgment. However, there is a lack of scientific, accurate, and timely technical knowledge about pesticides, further exacerbating the problem of pesticide residue.
2.2.3. Inadequate supervision causes excessive pesticide residues As a special market commodity, pesticides cannot be separated from government regulation. But so far, Chinese pesticide producers have been focused on quality management of pesticide products and the government is relatively weak in monitoring pesticide residues. In China, pesticides are regulated in sections and regulation is coordinated by the Food Safety Commission set up by the state council. Primary agricultural production, food processing, food circulation, and food consumption are supervised separately by the Department of Agriculture, quality inspection departments, industrial and commercial department, and the Department of Health. In this kind of management, responsibilities and roles are not always clear, which seriously affects the quality of supervision. At the same time, some pesticide companies, in pursuit of high profits, illegally sell some highly toxic pesticides that leave high levels of residues, in addition to selling fake and substandard pesticides.

3. Analysis of pesticide residues in agricultural products exported from China based on RASFF

3.1. Data Sources
The data in this section are mainly derived from RASFF, the EU Rapid Alert System for Food and Feed[22]. In order to analyze the impact of pesticide residues on the export trade in China since 2006, the time range of January 1, 2006 to December 30, 2016, was selected and the product category was food and the hazard category was pesticide residues.

3.2. Result analysis
From the output of RASFF, it can be seen that over the past 11 years, there have been 244 notifications of food exports in China due to pesticide residues (Figure 2). The specific results are detailed in the following sections.

3.2.1. High number of notifications due to excessive pesticide residues in China during the past five years During the past five years, the number of reported notifications due to excessive pesticide residues of China's agricultural exports increased rapidly: in 2012 and 2013, the number of notifications rose to 57 and 56, reaching the highest in history. The next two years saw a reduction in notifications with around 40 until 2016, the same as in 2011.

3.2.2. Notifications were mainly from the Netherlands, France, and Germany Since 2006, the number of notifications more than 10 times mainly from nine countries, of which the Netherlands reported the most, up to 39, followed by France and Germany. The other 64 notifications were scattered in the rest of the EU's 17 countries (Figure 3).

3.2.3. Tea, fruits, and vegetables are the main foods causing notifications. In the case of excessive pesticide residues, the proportion of tea was the highest, reaching 52.46%, accounting for more than half, followed by fruits and vegetables, accounting for 41.39% (Figure 4).
3.2.4. The punishment for notification of excessive pesticide residues is severe. In 244 cases of excessive pesticide residues, 43 were “imported with no authorization”, 42 were re-distributed, up to 36 were destroyed directly, 36 were officially detained, and 22 were recalled by the market (Figure 5). This has caused huge economic losses to the export enterprises and farmer’s income in China.

![Figure 5](image.png) Treatment of excessive pesticide residues.

**Figure 5.** Treatment of excessive pesticide residues.

3.2.5. Conclusions. Fruits, vegetables, and tea are all labor-intensive primary agricultural products, and are important types of agricultural exports in China, as well as being important sources of income for Chinese farmers. In recent years, excessive pesticide residues in food exported from China were frequently reported by EU countries. These reports have negative impacts on farmers’ incomes. These notifications should be dealt with by the relevant Chinese authorities.

Fruits [8], vegetables [23], and tea [24] are the kinds of agricultural products that use more pesticides in the process of planting. To reduce the amount of pesticide residues in fruits, vegetables, and tea in China, we should speed up the convergence and harmonization of Chinese pesticide residue standards with EU national standards using advanced technology to reduce pesticide residues and minimize export restrictions and losses.

4. Stakeholder identification and analysis

Stakeholder analysis is a methodological tool used in order to systematically gather and analyze qualitative information or findings. In general, from the farmer’s point of view, there are 8 kinds of stakeholders, namely the authority, farmers, pesticide producers or retailers, consumers, media, Industry Associations, scientific research, and international trade. Different stakeholders have different needs and the perceived attitudes (Table 2).

For stakeholders, there are six types of power and interests that will be grouped as follows: generally, the authority and industry association have both high power and high interest; farmers and international trade have high interest but only some power; scientific researchers and pesticide producers and retailers have some power and some interest; consumers have high interest but little power; finally, the media has little interest but is powerful.

As shown by the stakeholder analysis, different stakeholders have different levels of interest and should be managed in different ways. This analysis can help us to formulate appropriate policy to reduce pesticide residues (Figure 6).

5. Policy recommendation to reduce pesticide residues in Chinese agricultural product

5.1. Speed up establishment of a standard system

In order to reduce pesticide residues, it is important to strengthen inter-departmental collaboration; create unified national, industry, and local standards of methods to detect agricultural residues to reduce overlap; and to improve agricultural efficiency. In addition, it is necessary to speed up the improvement of technology for rapid detection of pesticide residues, and to promote a retrospective
system to strengthen the production process of pesticide residues with additional monitoring. Finally, it is crucial to strengthen the research into technologies for eliminating pesticide residues.

Table 2. Stakeholder Identification.

| Stake in the project | What do we need from them? | Perceived attitudes/risks | Risk if they are not engaged |
|-----------------------|----------------------------|--------------------------|-----------------------------|
| Authority             | Experienced staff to be involved in establishing regulations and standards; supervision and inspection of pesticide residues | Know the importance of pesticide residues, have done and will do many tasks to reduce pesticide residues | Without policy support, the project cannot be executed, or will face significant uncertainty |
| Farmers who plant tea, vegetable, fruits | Need them to raise awareness, comply with regulations, implement changes, and take action | Pesticides improve the production and export, lack of interest to reduce pesticide use | Could create significant barriers to project outcomes |
| Pesticide producers and users | Need them to raise awareness and comply with regulations | More concerned with profit than safety | Could be the barriers to project or plan |
| Domestic and international consumers | Increase awareness, take better protective measures, wash food to reduce pesticide residues | Concern about food quality, integrity, safety | They are advocates of the project |
| Media                 | Put pressure on the government and food production system | Lack of interest in project, only interested in hot issues | Could be advocates, or barriers to the project |
| Agricultural products or food industry association | Provide information about the industry | Worried about industry profits | Data may not be obtainable |
| Scientific research   | Find scientific methods to reduce pesticide use | Concern about pressure of adapting the new method | Lack of scientific research data |
| International trade   | Increase foreign exchange, reduce the export risk | Worried about the use of new detection methods | Could bring barriers to implementation and delay progress |

5.2. Develop organic biological pesticides and carry out comprehensive prevention and control
To control pesticide residues in China, the following must be done: phase out high toxicity pesticides; consider pesticides that leave high residues in violation of the guidelines for pesticide use; advocate for organic and green pesticides. Organic or green pesticides include the use of bacteria or their metabolites for insect and weed control. In addition, make continuous efforts to provide farmers with high efficiency, low toxicity, and low residue, environmentally friendly pesticides, and pay attention to the research on biological pesticides and biomimetic pesticides [25].
5.3. Strengthen international exchanges and cooperation
Cooperate with the European Union, the United States, Japan, and other regions and countries to develop technology for limiting pesticide residues and to manage pesticides on. Speed up coordination between regions, and promote development of international trade of agricultural products. At the same time, establish an early warning mechanism for agricultural exports and make full use of World Trade Organization rules to protect enterprises in China.

5.4. Publicize information and knowledge
In the United States, government departments have intensified publicity and guidance for pesticide users and agricultural products. As a result, the residual rate of pesticide residues in domestic agricultural products is not more than 2%, according to the FDA's five-year monitoring results [26]. In order to implement changes similar to the US, the public needs to be educated about pesticides and pesticide residue standards and farmers' understanding and awareness of pesticide toxicity needs to be improved. Additionally farmers should be informed about scientific methods of eliminating pests and diseases, to avoid misuse or improper use which may lead to excessive pesticide residues. To address this, a well-informed system of scientific use of pesticides should be put in place and professional advice should be readily available to farmers so they can make timely and well informed decisions on the use of pesticides.

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