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PESTICIDE POLLUTION IN CHINA

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ABSTRACT

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Pesticides are chemical substances that are utilized for killing pests and preventing diseases artificially. The excess pesticides are secreted in the soil or surrounding; and those hazardous compounds cause pollution.

Pesticide pollution is classified into three types: soil pollution, air pollution and water pollution. Soil pollution is the most serious problem among those three pollutions. Because most of the pesticides which are used in agriculture persist in soil which take long time to be degradable will affect to human, plant and animal.

The purpose of the thesis is twofold. It aims to analyze the current situation of pesticide pollution in China from three perspectives, the history of pesticides, their consumption, and the pollution they cause. Furthermore, it tries to alert the Chinese government to concentrate on pesticide pollution, by recognizing the problems of monitoring and controlling.

Key words
consumption, non-point source pollution, pesticides, synthetic fertilizers

ABSTRACT

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1 INTRODUCTION

China has a long history of utilizing pesticides, the first signs can be found from 500BC. However, the properties of contemporary pesticides are very different from archaic pesticides. The population of China is still increasing, so China is the most populous country in the world. It leads to high demand in food supply, hence; increasing in cereal production is the main object. Insects and diseases are the two most threatening problems that might affect the production of cereal. Through decades, the amount of pesticides using is still high and increasing in China.

The historical stages of Pesticide in China are based on the birth of the different kind of pesticides. There are three periods. The first was before 1970, when the most common pesticides were natural pesticides. The second period was between 1970 and 1980, the pesticides had been utilized during these years were inorganic synthetic pesticides. After 1980 was the third period of pesticides development, pesticides were similar to contemporary pesticides, and major pesticides were organic synthetic pesticides.

Consumption and trading amount of pesticides in China is large annually. In 2013, pesticides were exported to approximately 170 countries, such as Brazil, Vietnam, Thailand. The share value of pesticides exported to Asia was 60.51% and to South America was 58.41%. Pesticides were imported from 37 countries. The six major trade partners are France, Japan, Germany, the United States, Spain, and Turkey with a trade value of more than CNY 100 million, which accounted for 72.41% of the total import quantity and 82.77% of the import expenditures. China is a leading country in consuming pesticides with the annual amount of 1806 million kg. (Pariona 2017.)

Pesticides usage contaminates soil, water and air by releasing poison to the surrounding areas. Soil pollution is the toughest problem. The distance between soil and sprayed pesticides is close; therefore, the soil will percolate numerous chemicals. The type of pesticides, the soil characteristics, pH, humidity and temperature will decide how long pesticides remain in the soil and absorption rate.

Water pollution and air pollution are also caused by pesticides. Pesticides contain soluble substances (water dissolvable) and insoluble substances. The soluble substances will bring along the insoluble one to lakes, rivers, and oceans because of the water flow. About the air pollution, physical properties of pesticides directly influence on the severity of pollution. Organic pesticides gas and the low boiling point pesticides will vapor and condense in the atmosphere.

Monitoring of agricultural nonpoint source pollution started late in China, the monitoring infrastructure is weak and both the monitoring equipment and technologies are backwardness. China still has a long path of treating and controlling pesticides pollution. First, the Chinese government should find out the base of agricultural nonpoint source pollution as soon as possible. Then collecting data about the pesticides pollution in China rural area should be improved. Finally, the database of nonpoint source pollution of rural areas should be established. Hence the national scientific framework must be established clearly.

2 BACKGROUND

Chinese historical development of pesticide lasted long time ago. The first pesticide usage in China was founded in 500 BC (Taylor, Holley & Kirk. 2007). After the foundation of the People's Republic of China in 1949, the pesticides market developed dramatically and comprehensively. In 1949 the population of China was 541,670,000, and in twenty years it increased to 803,350,000 (ChinaToday 2017). Population development created a problem: high demand for food. Therefore, confirmation of the available food had become the most priority. In order to avoid the shortage of grain, it was necessary to enlarge the planting area, and also, to raise the amount of production.

The level of Chinese grain output between 1949 and 2000 fluctuated gradually. During 1949 to 1959, the grain output rose steadily, from about 113.2 million tons in 1949 to nearly 200 million tons in 1958. After that, there was a significant decline in 1961, only 140 million tons. The grain output in 1961 was 20% smaller than in the previous year. At the end of the 1950s China had suffered the most difficult period, because of natural disasters. Drought and flood destroyed crops, moreover, diseases and insects were also an issue. The Great Chinese Famine occurred from 1958 until 1961. (Wen 2003.)

After 1961, it seemed that China had recovered from the damage. The grain output grew steeply: in 1981 it reached about 322 million tons. In 1987, the total grain amount was about 400 million tons. It peaked in 1997 at around 500 million tons. Then, the trend had changed, and there was a slight decrease until 1999, to about 490 million tons. In 2000 the total grain output was as much as in 1997. (Wen 2003.)

To increase agricultural production, new cultivating methods appeared. Mechanization and genetically modified organisms (GMO) were applied. The plant grown from GMO seeds produce more food, survive well in bad weather conditions, and are resistant to insect attacks. Insect infestation is a considerable issue in agriculture, because it affects both the quality and quantity of crops. Thus, more and more pesticides are utilized to minimize the consequence caused by insect infestation. During the period from 1958 to 2003, the Chinese were more concerned about producing crops than caring about the pollution caused by pesticides. There was a sharp increment in population, from 653,460,000 in 1958 to 1,288 billion people in 2003. (ChinaToday 2017; The World Bank Group 2017.) To ensure food security, planting was promoted; therefore, there was a development in pesticides consumption.

3 HISTORY OF PESTICIDES

Although pesticides had been used by our ancestors for a long time, it is difficult to determine the first time pesticides had been used against the pests. Presently, pesticides play an important role in agriculture. Humans promote the advantages of pesticides and mitigate the disadvantages.

The history of pesticide development can be divided into three times periods. The first time was before 1870, and natural materials were the major components of pesticides. The second period was between 1870 and 1945, and the raw material used for pesticides changed to inorganic synthetic materials. The third period started after 1945, and organic synthetic materials were used instead of inorganic materials. (Taylor, Holley & Kirk 2007.)

3.1 Natural pesticides

In 2500 BC, Sumerians believed that sulfur compound could repel the pests, therefore, they sprayed smelling sulfur compound on their body to prevent insects from approaching. The Ebers Papyrus, one of the oldest medical documents contains more than 800 prescriptions that could be used as pesticides. In 1000 BC in Greece, Odysseus (Greek king of Ithaca) burned sulfur to fumigate his house to control pests. At the same time, Chinese had already used a mixture of mercury and arsenic to control body lice, furthermore, they used predatory ants to protect the citrus groves, which were attacked by caterpillars. (Taylor, Holley & Kirk 2007.)

Marcus Terentius Varro was an ancient Roman scholar and writer. He was the first person who found a chemical weed killer. He indicated that amurca produced from crushed olives could kill ants, moles and weeds. Palladius was a Roman and the author of Opus Agriculturea, who documented the use of amurca and cucumber liquid extraction to repulse caterpillars from cabbage. (Taylor, Holley & Kirk 2007.)

3.2 Inorganic synthetic pesticides

Between 1750 and 1880, the agricultural revolution happened in Europe. European countries were concentrated on output of crops as well as crop protection. Scientist discovered two kinds of insecticides, pyrethrum and derris, which could cut down insects efficiently. A Copper sulfate solution was used to treat bunt disease in wheat in 1807. Later, in 1867 Paris green, a new insecticide was invented, which was a mixture of copper and arsenic. This insecticide controlled effectively the beetle in potato and grape growing. (Taylor, Holley & Kirk 2007.)

The common formations of inorganic pesticides are crystalline or salt that are soluble in water easily. In the past, the main components in pesticides were sulfur and lime.

3.3 Organic synthetic pesticides

In 1948, Paul Müller was awarded the Noble prize in Physiology or Medicine for the discovery of the insecticide DDT. DDT was the first man-made organic insecticide. In World War II, DDT saved several thousand people's lives by killing typhus-carrying lice and malaria-carrying mosquitoes. (Taylor, Holley & Kirk 2007.) After World War II, Benzene hexachloride (BHC), Aldrin Dieldrin, Endrin and phenoxy herbicides such as 2,4-D, 2,4-DP (1944), and 2,4,5-T were synthesized and marketed. These chemicals were the most important insecticides at that time and were used extensively. The advantages of insecticides include, that they work efficiently on various objectives. However, they take a long time for decomposing and their manufacturing cost is high compared to natural and inorganic pesticides (Taylor, Holley & Kirk. 2007).

4 TRADE AND USAGE OF PESTICIDES

Using pesticides prevents the growth of weeds and insect infestation; crops do not require as much work to take care of; therefore, pesticides are applied widely. In 2006 and 2007, the expenditure on pesticides globally was USD 35.8 billion and USD 39.4 billion. Table 1 shows detailed information about the pesticide expenditures in 2006 and 2007. Herbicides including plant growth regulators were in the first place, and amounted for approximately 40% of the total value. In the second place were insecticides, which accounted for about 29% of the total expenditures, followed by fungicides and other pesticides, including nematicides, fumigants, and other miscellaneous pesticides.

TABLE 1. World pesticide expenditures (Grube, Donaldson, Kiely & Wu 2011)

Year and Pesticide Type	**World Market**	
	Millions of USD	%
2006		
Herbicides	14247	40
Insecticides	10259	29
Fungicides	7987	22
Other	3320	9
Total	35814	100
2007		
Herbicides	15512	39
Insecticides	11158	28
Fungicides	9216	23
Other	3557	9
Total	39443	100

An enormous amount of pesticide is utilized annually, according to Table 1, the expenditure in 2007 was approximately USD 4000 million higher than in 2006. In both 2006 and 2007, approximately 5.2 billion pounds of pesticides were used globally. According to the data found in Table 2, herbicides accounted for the highest portion of total use, followed by insecticides and fungicides.

TABLE 2. Amount of pesticide used around the world (Grube, Donaldson, Kiely & Wu 2011)

Year and pesticide type	World Market	
	Million lbs.	%
2006		
Herbicides	2018	39
Insecticides	955	18
Fungicides	519	10
Other	1705	33
Total	5197	100
2007		
Herbicides	2096	40
Insecticides	892	17
Fungicides	518	10
Other	1705	33
Total	5211	100

4.1 The United States

The United States is one of the biggest pesticide using countries. In 2006 and 2007, the consumption of pesticides was approximately one third of the world expenditures; however, the used amount was about one fifth of the world total usage.

TABLE 3. Expenditures and usage of pesticide in U.S (Grube, Donaldson, Kiely & Wu 2011)

Year and Pesticide Type	**Expenditures**		**Percentage of World Market**	**Consumption**		**Percentage of World Market**
	Millions of Dollar	%		Million lbs	%	
2006						
Herbicides	5673	48	40	498	44	25
Insecticides	4091	35	40	99	9	10
Fungicides	1165	10	15	73	6	14
Other	8550	7	26	457	41	27
Total	11784	100	33	1127	100	22
2007						
Herbicides	5856	47	38	531	47	25
Insecticides	4337	35	39	93	8	10
Fungicides	1375	11	15	70	6	14
Other	886	7	25	439	39	26
Total	12454	100	32	1133	100	22

TABLE 4. Pesticide production, imports, exports and supply in amount of active ingredient in US (Grube, Donaldson, Kiely & Wu 2011)

	Active Ingredient (Billions of pounds)
	Average of 2006 and 2007
Production	1,2
Imports	0,2
Total supply	1,4
Exports	0,3
Net supply	1,1

From 2006 to 2007, the used amount of pesticides grew slightly, whereas the amount of insecticides, fungicides and others decreased. The reason behind this is that new pesticides with improved efficiency were invented and utilized. The government noticed pesticide pollution and devised a strategy to decrease using pesticides thus minimizing their impact on the environment and humans. The National Academy of Sciences estimates that yearly between 4,000 and 20,000 cases of cancer are caused by pesticide residues in food. (Grube, Donaldson, Kiely & Wu 2011.)

4.2 Europe

Generally, European countries apply advanced technologies and more machinery than in some developing countries in Southeast Asia or Africa. Serbia, Montenegro, Albania and Moldova have a large proportion of farm workers in Europe at about 30% of the labor force. By contrast, England, Belgium, Holland and Sweden have the lowest proportion rate in Europe, at just about 4%. (Grube, Donaldson, Kiely & Wu 2011.)

The main cereal products in Europe are wheat (44.7%), grain maze and corn-cop mix (20.8%), barley (19.95%), oats (2.7%), and rye (2.6%), with the following countries leading the production: France (54209 million tons), Germany (45401 million tons), Turkey (34913 million tons), Poland (29849 million tons), and Spain (24115 million tons). (Eurostat 2017.) Because of the condensed agricultural activities, the quantity of consumption and trading amount of pesticide in Europe is significant. In the European countries where pesticides are used instead of modern and efficient techniques to protect crops from insects, such as Serbia and Montenegro; and also in France and Russia, the largest crop producers in Europe, also use an extensive amount of pesticides (FAOSTAT 2014).

TABLE 5. Top five pesticide trading countries in Europe in 2012 (FAOSTAT 2014)

Country	**Trade**		**Percentage of Europe Market (%)**
	Import Value (1000 USD)	Export Value (1000 USD)	
France	2229339	3522983	21.9
Germany	1756579	3649572	20.6
Spain	821272	1144618	7.5
United Kingdom	976603	1488182	9.4

Belgium	883997	1788661	10.2
Total (European Union)	11340702	14885200	NA

Table 5 shows the trading business in Europe, which was mostly concentrated in five countries amounting to approximately 70% of the total European trading market. France was the biggest pesticide trading country in Europe. This phenomenon occurs usually related to the position of agriculture among European countries, of which France is the largest agriculture producer, with 9478000 ha of cultivation (Eurostat 2017). France's share was 21.9% of the pesticide trade, followed by Germany with 20.6%.

TABLE 6. Top five countries of the use amount of pesticide in Europe in 2003 (Eurostat 2007)

Country	Fungicides	Herbicides	Insecticides	Growth regulators	Total	Percentage of Europe Market (%)
France	33983	21681	3872	2217	61753	28.1
Spain	16664	8877	6180	94	31815	14.5
Italy	18435	5298	7072	24	30828	14
Germany	8106	12529	493	2112	23240	10.6
United Kingdom	3781	9161	827	1151	14920	6.8
Total (European Union)	107574	83934	21404	6859	219771	NA

Similar to the pesticides trading business in Europe, the quantity of pesticides used is concentrated in almost the same five countries, namely France, Spain, Italy, Germany and United Kingdom. Their share is over 73% of the European usage. When comparing between tables 5 and 6, Belgium was replaced by Italy. The countries with the largest cultivating areas such as France, Spain and Germany are the leading countries in pesticide usage as well as trading.

According to the data reported by Eurostat, the amount of pesticides used in the European countries increased sharply in the 1900s. Until 1999, it was decreasing continuously. There was a steady decrement in the use of fungicides because of reservation of some profitable organism in plant.

4.3 China

China has a total area of approximately 9.6 million square kilometers, of which only one eighth is arable, that is nearly 1.35 million square kilometers. In 2001, 82.8% of the arable land area was used for cereal planting, with the rest used for forestry and raising livestock. The principal grain-producing areas are the places located to the East of the Urad Middle Banner of the Inner Mongolia autonomous region, South of the Great Wall, and East of the Qinghai-Tibet Plateau. The total grain cultivation area was about 95%. The percentage of sown area in the Western part of China was 5% of the total, and the proportion of grain output was only 4%. (National Bureau of Statistics of China 2014.)

TABLE 7. Pesticide import and export in China between 2002 and 2012 (FAOSTAT 2014; National Bureau of Statistics of China 2014)

Year	Import Value (million USD)	Import quality (10000 tons)	Export Value (million USD)	Export quality (10000 tons)
2002	136.09	2.7	680.2	22.2
2003	133.99	2.8	820.5	27.2
2004	146.8	2.8	1277.2	39.1
2005	182.22	3.7	1491.4	42.8
2006	212.81	4.3	1136.2	58.3
2007	231.44	4.1	1455.8	NA
2008	295.38	4.4	2196.5	NA
2009	334.29	4.4	1555.3	NA
2010	421.27	5.1	1906.2	NA
2011	488.7	5.3	2571.3	140.7
2012	592.3	6.9	3028.5	159.9

The statistics about pesticides are mostly gathered independently in China as non-government projects, and this can be demonstrated by comparing the import value/quantity and export value/quantity, as seen in Table 7. Export value and quantity were always significantly higher than import value and quantity. Except in the year 2009, when the export value decreased because of the financial crisis. From 2002 to 2012, both import- export values, and import- export quantities increased continuously, and presented a growth trend. During this period the Chinese trade increased sharply, especially the exports. The reason could be Chinese successes in studying pesticides.

TABLE 8. Each category of pesticides of import and export in China in 2008 (CCPIA 2014)

Category	Import (million USD)	Growth rate %	Import (1000 tons)	Growth rate %	Export (million USD)	Growth rate %	Export (1000 tons)	Growth rate %
Insecticides	60	14.8	8	11.1	510	24.4	136	-1.9
Herbicides	110	35.7	19	5.0	1230	72.2	277	1.8
Fungicides & Bacteri-cides	100	20.8	13	-2.7	240	38.3	55	5.1
Total	300	27.6	44	7	2020	49.7	485	1.5

China was one of the top ten countries for exporting pesticides between 2002 to 2007. In 2002, China ranked fifth with a value of USD 680,181.2 thousand. The value of pesticides China exported increased slightly until 2005 and reached the 3rd position with USD 1,491,443 thousand. Then in 2006, it declined to USD 1,136,184.4 thousand, to reach USD 1,455,784 thousand in 2007. (FAOSTAT 2007.)

Since rice is the most cultivated cereal in China, most of the pesticides are used on the paddy fields. The sale of pesticides used on rice accounted for 15% of the total sales, reaching 538 million USD in 2006. The sale of pesticides used on vegetables was 24.2% of the total. Since 2006 pesticide usage amount decreased to about 89.44 million tons on cereals, 1.65 million tons on cotton, 2.53 million tons on oilseeds and 78 million tons on vegetables. (Editorial Board of Chinese Yearbook on Agriculture 2007.)

TABLE 9. Amount of pesticides usage in China between 2005 and 2011 (National Bureau of Statistics of China 2014)

Years	Usage amount (million tons)	Growth rate %
2005	1.46	5.0
2006	1.54	5.5
2007	1.62	5.2

2008	1.67	3.1
2009	1.71	2.4
2010	1.76	2.9
2011	1.79	1.7

5 POLLUTION OF PESTICIDES IN CHINA

Pesticides are chemicals used by humans for attracting, exterminating or mitigating pests. Globally approximately 5.6 billion pounds of chemical pesticides are sprayed annually. Actually, 35% of the pesticide are functional for pest control, and the rest, 65% is excess. Pesticides are not only utilized for protecting plants from insects, but are also widely utilized for disinfection. Except for a few natural pesticides used in some remote areas, most pesticides are manufactured by humans. (Tang & Li 1998.)

Pesticide pollution is defined by the negative impact of the pesticides on the environment and humans. Undesired and unexpected effects would lead to a set of environmental concerns that affect the environment and human health. Pesticides are carried by runoff and are spread widely the by wind or water flow, they potentially affect other species as well as the dwellers in the contaminated areas. Applying pesticide regularly will cause pesticides resistances in pests, therefore higher amounts of pesticide or stronger ones need to be used. This results in serious environmental pollution.

As mentioned earlier, pesticides can cause three kinds of pollution, which include air pollution, water pollution and soil pollution. They interact with each other, and the damage can be extensive. Although the Chinese government has conducted a series of response measures for controlling pollution, pesticides are still an inevitable part of the problem.

In 2013 in China the national grain sown area was 111,951.4 thousand hectares, which increased by 0.7% from 2012. The national grain production was 601,935 thousand tons, which rose by 2.1% from 2012. In 2012, the usage amount of pesticides was 1800 thousand tons. However, the data of the usage amount of pesticides in 2013 was absent in the report released by the National Bureau of Statistics of China, and the accurate number is still unavailable. (National Bureau of Statistics of China 2014.)

TABLE 10. The grain production in each province in 2013 (National Bureau of Statistics of China 2014)

Province	Sown area (Thousand hectares)	Production (Thousand tons)	Province	Sown area (Thousand hectares)	Production (Thousand tons)
Beijing	159	961	**Zhejiang**	1253.7	7339
Tianjing	332.8	1747	**Anhui**	6625.3	32796
Hebei	6315.9	33650	**Shandong**	7294.6	45282
Shanxi	3274.3	13128	**Henan**	10081.8	57137
Neimenggu	5617.3	27730	**Sichuan**	6469.9	3387.1
Liaoning	3226.4	21956	**Jiangxi**	3690.9	21161
Jining	4789.9	35510	**Hunan**	4936.6	29258
Heilongjiang	11564.4	60041	**Yunnan**	4499.4	18240
Shanghai	168.5	1142	**Guangxi**	3076	15218
Jiangsu	5360.8	34230	**Hubei**	4258.4	25013

TABLE 11. Application dosage of chemical pesticides in each province in China (kg/ha) (Zhang, Jiang & Ou 2011)

Dosage level	Province or city	Dosage	Dosage level	Province or city	Dosage
I (>6 kg/ha)	Shanghai	12.72	**II (3~6 kg/ha)**	Guangdong	5.52
	Shandong	10.55		Jiangxi	5.32
	Jiangsu	9.43		Hunan	5.15
	Hubei	7.29		Fujian	4.69
	Hainan	7.12		Hebei	4.40
	Anhui	7.10		Liaoning	3.45
	Henan	7.07		Tianjing	3.12
	Zhejiang	6.38	**III (1.5~3 kg/ha)**	Guangxi	2.54
IV (0.75~1.5 kg/ha)	Shanxi	1.49		Chongqing	2.47
	Sichuan	1.24		Beijing	2.22
	Yunnan	0.89		Jilin	2.01
	Gansu	0.78		Heilongjiang	1.8

In China, 13 out of 23 the provinces are major grain producing areas, as can be seen from Table 10. According to the data published by the state administration in 2011 (National Bureau of Statistics of China 2014), grain production of these thirteen provinces was 75.4% of the total grain production in China. These thirteen provinces are located in the Central, Eastern and Northern parts, and have used pesticides for a long time, which causes serious environmental pollution. Therefore, the habitants in those areas are threatened by the pollution. Excess pesticides can be present in the biosphere, and hence the atmosphere, hydrosphere, lithosphere and ecosphere are all influenced. The lithosphere is affected heavily, because most of excess pesticides enter the soil, and even small portions of pesticides can directly contaminate the soil.

5.1 Soil pollution

China is the biggest producer and consumer of pesticides globally, as pointed out in chapter 4.3. Because of the high crop production, enormous consumption of pesticide is required. In some areas, in order to achieve the production goals set by the government, hazardous but efficient pesticides are still utilized by the farmers.

Pesticide usually has a longer retention time in the soil where the concentration of organic matter and clay is high. The reason is that clay and organic matter combine and create composite colloids. The advantage of composite colloids is the adsorption capacity, because it produces a stable insoluble binding residue, which can combine with pesticides. The new compounds are less toxic. Pesticides can affect the pH and the humidity of soil, therefore, the degradation of microbes in the soil is also affected. However, microbes' degradation is the major natural treatment for pesticide pollution. (Sun, Linxiu, Linzhang, Fusuo, Norse & Zhaoliang 2012.)

Soil consists of inorganic and organic colloids that are responsible for absorption. When the colloids react with the pesticides, they form a chemical compound which is less toxic. From another perspective, soil adsorption is a self-recovery method from the pollution of pesticides. Normally, the ability of absorption and the toxicity of pesticides are inversely proportional. (Sun et al. 2012.)

The ability of absorption is influenced by four factors. The first is the colloid in the soil. Pesticides have a positive charge, and colloids have negative charge, so they will attach to each-other. Therefore, the absorption capacity of colloids defines absorption ability. Generally, the absorption capacity increases gradually, in the following order: organic colloid ＞ vermiculite ＞ montmorillonite ＞ illite ＞ chlorite ＞ kaolinite (Sun et al. 2012.) For instance, the absorption ability of vermiculite with saturated sodium ions is greater than the vermiculite with saturated calcium ions. The characteristic of pesticide is also a factor that affects absorption ability. Different molecular structures have a direct effect on the adsorption ability of the soil. For example, the soil would adsorb a bigger portion of a pesticide which has an –NH2 functional group.

TABLE 12. Residual levels of Organochlorine Pesticides (OCPs) in the soils in China (Zhang, Jiang & Ou 2011)

Region	Monitoring years	Soil type	OCPs	HCH (μg · kg^{-1})	DDT (μg · kg^{-1})
Beijing	2004	Various types	DDT, HCB, chlordane, Aldrin, etc.	NA	0–1830 (Mean:76.8)
Nanjing	2002–2003	Crop land	DDT, HCH, and their metabolites	2.7–130.6 (Mean:13.6)	6.3–1050.7 (Mean: 64.1)
Yingchuan	2007	Various types	DDT, HCH, HCB, etc.	0.31–74.22 (Mean: 0.85)	0.28–1068.4 (Mean: 2.24)
Xiangjiang river valley	2004	Various types	DDT, HCB, chlordane, Aldrin, etc.	NA	0.33 – 3244 (Mean:132.3)
Guangdong	2002-2005	Agri., soils	DDT, HCH, chlordane, Aldrin, etc.	Na-104.38 (Mean: 5.9)	Na-157.75 (Mean:10.18)
Tangshan	2008	Various types	DDT, HCH	2.73-32.3 (Mean: 5)	11.09-141.07 (Mean: 66.4)

Organochlorine pesticides are insecticides composed primarily of carbon, hydrogen and chlorine. The degradation rate of organochlorine compounds is very slow; therefore, it remains underground for a long period after it is applied. The most notorious organochlorine pesticide is Dichlorodiphenyltrichloroethane (DDT). China has prohibited the use of OCPs in 1983, however, due to its low degradation ability and serious damage to the soil, as shown in Table 12, the amounts of residues is still abundant and is still a hazard for the soil and thus humans.

Pesticide persistence in soil is categorized into three types, based on the half-life degradation: low persistence, moderate persistence, and high persistence. Half-life degradation is the needed time for half of the amount of the pesticide to decompose. The half-life of low persistence pesticides is 30 days, for moderate persistence this is 30-100 days, and for high persistence pesticides this is more than 100 days.

Low persistence pesticides are Aldicard, Captan, Dalapon, Dicamba, Malathion, Methyl Parathion, Oxamyl, 2,4- D, and 2,4,5- T. Moderate persistence pesticides include, among others, Aldrin, Atrazine, Carbaryl, Endrin. High persistence pesticides are TCA, Bromacil, Chlodrane, Lindane, Picloram, Trifluralin, and paraquat. (Cornell University 1993.)

TABLE 13. Remaining time of some organochlorine pesticides (Tang & Li 1998)

Pesticide	5% residual (years)	Mean (years)
DDT	4 – 30	10
Dieldrin	5 – 25	8
Lindane	3 – 10	6.5
Chlordane	3 – 5	4
Telodrin	2 – 7	4
Heptachlor	3 – 5	3.5
Aldrin	1 – 6	3

Degradation and sorption are both factors influencing the persistence of pesticides in the soil. Microbes play a vital role in the soil that affect pesticide degradation. Microbes use pesticide as food and digest them. However, if organochlorine pesticides or other pesticides which are difficult to degrade are in the soil, pesticides will accumulate and these organisms store pesticides. Pesticides can be used by plants as nutrients and will be stored in living organisms. Because of the food chain, they transfer to other organisms. (Cornell University 1993.)

The evaluation of the risk of pesticide pollution is according to the inputs and outputs of nitrogen. The inputs of nitrogen include synthetic single and compound nitrogen fertilizers, whereas the outputs of nitrogen are the concentration of nitrogen in the harvested crop. If the amount of both inputs and outputs of nitrogen are higher than 180 kg/ha, then the risk class is classified as high. If the quantity is between 100 kg/ha and 180 kg/ha, potential class has been identified., whereas low class means values lower than 100 kg/ha. The average concentration of DDTs in China is 60 µg/kg, while the average concentration is 8.7 µg/kg. The concentration of DDTs in Eastern China was 14 to 15 times higher than in the South and Southwest. The concentration of HCHs in the South is 2 to 4 times higher than the concentration in the North. (Sun et al. 2012.)

5.2 Water pollution

Water pollution is a side pollution of pesticides, since pesticide residue enters the hydrosphere with the rain water or with the irrigation water. On the surface, runoff water would dissolve soluble residues and flow to lakes, rivers or oceans with insoluble residues eventually. The concentration of residues in water is restricted by six factors. These are solubility, distance between the water and the applied pesticide, weather, soil type, crop type and the pesticide application method. The balance of hydro nutrients will be disrupted by the pesticide polluted water.

Eutrophication can be caused by high levels of nitrogen and phosphorous. However, eutrophication is only one potential instance that pesticide pollution could cause. Besides eutrophication, organic residues of the pesticide in water could create severe problems to the environment. According to the data published in the primary appraisal of pollution of lakes of China, approximately half of the 131 major lakes were eutrophic and the eutrophication situation of 75% lakes was getting worse. In 2000, the frequency of red tides, “a discoloration of seawater caused by a bloom of toxic red dinoflagellates” (Oxford Dictionary 2017) was 28, but until 2008, the frequency was 2,5 times more than eight years before. Moreover, the cumulative area of red tides in 2008 has reached 13,738 km^2. (CCPIA 2014.)

In China, water quality can be identified with five grades, grade I and grade II mean that the water quality is excellent; and being protected. Grade III shows that the water is of good quality. Grades IV, V and V plus mark light pollution, medium pollution and serious pollution, respectively. Normally, Grade IV water and above cannot be utilized for human consumption, only in industries and agriculture. In 2008, over 60% of the water was above grade IV.

Compared with the situation of pollution in seven rivers, the circumstance of 28 major lakes is even more serious. The water of only 20% of the lakes is between grades I to III. However, these results can be expected, since lakes are one of the destinations for runoff or underground water. Because of the current flow and the properties of lakes, the settling rate of pesticide will be different. Over a long period of time, the high concentration of pesticides will affect the quality of the lake negatively. In Jiangsu province, Zhejiang province and Shanghai, which are the last three provinces the Yangtze flows through, the nitrogen concentration in the water is more than 20 mg/L. (Zhang 1999.) The concentration of nitrogen in water in the sampling wells drilled in Beijing, Tianjin and Tangshan is over 11.3 mg/l, and the highest sample reached 68 mg/l (Zhang & Li 1996).

Pesticide residues polluting the water source lead to various consequences. The water resources are affected causing a shortage of fresh water and an imbalance in the ecosystem. Water treatment plants should be considered as the solution for the areas exposed.

TABLE 14. Residual levels of OCPs on the water bodies of China (Zhang, Jiang & Ou 2011)

Water body	**Monitoring year**	**Water**	**OCPs**	**HCH (ng/L)**	**DDT (ng/L)**
Suburb of Beijing	2006	Surface water	HCH, DDT	3.87 – 146.62	NA – 13.98
Middle-downstream, yellow river	2006	Surface water	DDT, HCH, HCB	0.73 – 48.09	0.06 – 10.04
Pearl River	2006	Shallow ground water	DDT, HCH, HCB, heptachlor	NA – 8	NA – 3.41
Port Dongzhai, Hainan (Dry season)	2006	Surface water	DDT, HCH, dieldrin, endrin etc.	2.66 – 8.2 (Mean: 5.28)	5.91 – 54.59 (Mean: 10.28)
Port Dongzhai, Hainan (Wet season)	2005	Surface water	DDT, HCH, dieldrin, endrin etc.	0.54 – 2.24 (Mean: 0.28)	0.28 – 14 (Mean: 6.52)

5.3 Air pollution

The air pollution of pesticide is similar to fine particulate matter pollution. Generally, there are two major ways pesticides cause air pollution. First, pesticide particles are suspended in the air during implementation and transferred by wind to other places. The second is about the physical properties. The pesticide is available in the atmosphere in gas form, and the chemical remains on the plant will vapor in suitable weather conditions.

Uncertainty is deciding the difficulty of pollution control. Vaporization of pesticide depends on the surrounding environment, different seasons and different weather conditions could cause unpredictable results. Moreover, the spread range is impossible to predict. Pesticide can combine with the dust particle and move freely in the air.

TABLE 15. Residuals of OCPs in the air in China (Zhang, Jiang & Ou 2011)

Region	Type	Monitoring year	OCPs	DDT (ng/m^3)
Tongzhou district, Beijing	Gas	2005	DDT, dieldrin, endrin	0.0111 (spring) 0.152 (autumn)
Central town, Beijing	TSP*	2002	DDT, HCH	0.962 (summer)
Anhui	NA*	2005	DDT, dieldrin. endrin, etc.	0.318
Jiangsu	NA	2005	DDT, dieldrin, endrin etc.	0.772
Hunan	NA	2005	DDT, dieldrin, endrin etc.	1.11
Hubei	NA	2005	DDT, dieldrin, endrin etc.	0.336
Central town, Tianjing	TSP	2002	DDT, HCH	1.874 (summer)

*TSP: total suspended particulate NA: not available

The amount of pesticide residue in the air in the rainy season is lower than during the other season, because the rain drops bring them back to the ground. This is how the pollution cycle is constructed.

6 EFFECTS ON FLORA AND FAUNA

Nutrients absorbed by plants were degraded by organisms in the soil. After pesticides enter the soil, organic compounds will be decomposed by these organisms, and then absorbed by plants. Hazardous substances are produced during this process. After the plants absorb a substantial amounts of contaminants, mortality or drop production of plants could occur directly. (Zhang, Jiang & Ou 2011.) Furthermore, plants produce energy through photosynthesis. One specific condition for photosynthesis to occur is the availability of carbon dioxide, which is a gas diffused through the plants' leaves. If significant amounts of pesticides cover the leaves, then the plants cannot get enough carbon dioxide, and without it photosynthesis cannot happen.

Large amounts of pesticides in the soil can cause ecological imbalance (Zhang, Jiang & Ou 2011). For example, mortality of earthworm could be caused by pesticides, moreover, plants cannot gain enough nutrition for growing. Pesticides kill insects without distinguishing, which means that pollen insects can also be killed. Without pollination, plants will not grow up and reproduce.

The physiology of fauna is similar to that of human beings. Animals are affected by consuming polluted plants. Normally, there are three transfer paths of pesticides from flora to fauna. The first path is soil-terrestrial plant - herbivores. The next is soil - invertebrates in soil – vertebrates - carnivores. The last path is soil – plankton - fish and aquatic organisms - piscivorous animals. (Zhang, Jiang & Ou 2011.) Once the pesticides enter animals, the pesticides which decompose easily will travel in the body and attack the visceral units. However, pesticides will be stored in the body, especially fat-soluble pesticides, such as DDT. DDT can dissolve in fat, therefore the residual time of DDT is very long and it becomes part of the body.

The effect on human health is inevitable, and more serious than that on the flora and fauna. Pesticides can affect human through the air, the water and the meat of animals. This demonstrates that even though humans are the biggest cause of pesticide pollution, but they are also the biggest victims of it. Pesticides can cause many diseases to humans, such as tumors, genetic changes, blood and nerve disorders, endocrine disruption, coma or even death. Most of the diseases caused by pesticides are long-term and are difficult to cure.

7 CONCLUSION

Pesticide pollution has been neglected for a long time. Industrial areas are the biggest, but not the sole distributors of pollution. Most people think of agriculture as the green sector, and never realize the pollution that pesticides cause. From the farmers' side, increasing the amount of pesticides used could result in improved production, however, they do not realize the damage of pesticides (Watts 2010).

The government usually considers the origin of pesticide pollution to be from industrial and urban areas, and the funds are usually spent on treating industrial pollution. Because of the limited thinking and the shortage of funds, the Ministry of Agriculture of the People's Republic of China has not yet established a complete agricultural nonpoint source pollution control system. They have not had a specific department responsible for controlling and treating pesticide pollution. Local governments are fragmented and have a lack of coordination.

Presently, improving the system of monitoring agricultural nonpoint source pollution should be the first step, by establishing a department responsible for monitoring and controlling pesticide pollution. Enhancing the cooperation between local governments would prevent fragmentation occurring again. States should promote using less pesticides and, instead, using organic fertilizers and animal ecological farming techniques, and at the same time teaching farmers the correct ways of using pesticides and educating them about their disadvantages. Farmers should be encouraged to apply economically friendly farming technologies. Farmers should realize what harms pesticides might cause.

States should establish a foundation for controlling agricultural nonpoint source pollution, by allocation through central government, by issuing public welfare lotteries, and accepting social donations and other resources that can raise funds. The foundation could provide funding for treating and controlling agricultural nonpoint source pollution. Such a foundation could serve as a solid basis.

REFERENCES

China Crop Protection Industry Association (CCPIA). 2014. China Agrochemicals. Available: http://www.agrochemex.org/wp-content/uploads/2014/07/China-Agrochemicals-2014-June-print.pdf. Accessed 30 August 2014.

ChinaToday. 2017. China Population Statistics and Related Information. Available: http://www.china-today.com/data/china.population.htm. Accessed 20 December 2017.

Cornell University. 1993. Movement of Pesticides in the Environment. Available: http://pmep.cce.cornell.edu/profiles/extoxnet/TIB/movement.html. Accessed 21 December 2017.

Editorial Board of Chinese Yearbook on Agriculture. 2007. Chinese Yearbook on Agriculture. Beijing: China Agriculture Press.

Eurostat. 2007. The use of plant protection products in the European Union. Available: http://ec.europa.eu/eurostat/documents/3217494/5611788/KS-76-06-669-EN.PDF. Accessed 20 September 2014.

Eurostat. 2017. Agricultural production - crops. Available: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_production_-_crops#Cereals. Accessed 21 December 2017.

Food and agriculture organization of the United Nations (FAOSTAT). 2012. Pesticides, trade. Available: http://ref.data.fao.org/dataset?entryId=27cb057d-ac7a-40f3-99bf-54d9baf2274c. Accessed 21 December 2017.

Food and agriculture organization of the United Nations (FAOSTAT). 2014. Statistics data. Available: http://www.fao.org/faostat/en/#home. Accessed 15 September 2014.

Grube, A., Donaldson, D., Kiely, T. & Wu, L. 2011. Pesticides Industry Sales and Usage. 2006 and 2007 Market Estimates. Available: https://www.epa.gov/sites/production/files/2015-10/documents/market_estimates2007.pdf. Accessed 15 August 2014.

National Bureau of Statistics of China. 2014. Statistics data. Available: http://www.stats.gov.cn/english/. Accessed 5 October 2014.

Oxford Dictionary. 2017. Red tide. Available: https://en.oxforddictionaries.com/definition/red_tide. Accessed 21 December 2017.

Pariona, A. 2017. Top Pesticide Using Countries. Available: https://www.worldatlas.com/articles/top-pesticide-consuming-countries-of-the-world.html. Accessed: 20 December 2017.

Sun, B., Zhang, L., Yang, L., Zhang F., Norse, D. & Zhu, Z. 2012. Agricultural non-point source pollution in China: causes and mitigation measures. Available: https://www.ncbi.nlm.nih.gov/pubmed/22311715. Accessed 21 December 2017.

Tang, C.C & Li, Y.X. 1998. Pesticides Chemistry. Tianjing: Nankai University Press.

Taylor, E. L., Holley, A. G. & Kirk, M. 2007. Pesticide Development – A Brief Look at the History. Available: https://sref.info/resources/publications/pesticide-development---a-brief-look-at-the-history. Accessed 21 December 2017.

The World Bank Group. 2017. Population, total. Available: https://data.worldbank.org/indicator/SP.POP.TOTL. Accessed 20 December 2017.

Xinhua. 2012. China's rural pollution to be monitored soon. Available: http://www.china.org.cn/environment/2012-03/12/content_24872607.htm. Accessed 21 December 2017.

Yuan, X.Y. 2000. Primary appraisal of pollution for lakes of China. Volcanology and Mineral Resources 21, 128–136.

Watts, J. 2010. Chinese farms cause more pollution than factories, says official survey. Available: https://www.theguardian.com/environment/2010/feb/09/china-farms-pollution. Accessed 21 December 2017.

Wen, T. 2003. Relationship between cereal and population in China. Available: http://paper.usc.cuhk.edu.hk/Details.aspx?id=2300. Accessed 12 August 2014.

WenJun, Z., FuBin, J. & JianFeng, O. 2011. Global pesticide consumption and pollution: with China as a focus. Available: http://www.iaees.org/publications/journals/piaees/articles/2011-1%282%29/Global-pesticide-consumption-pollution.pdf. Accessed 12 August 2014.

Zhang, F.S. 1999. Some consideration to the improvement of nutrient resources utilization efficiency. 2012. Beijing: Soil Science Society of China.

Zhang, W. L., Tian, Z.X., Zhang, N. & Li, X. Q. 1996. Nitrate pollution of groundwater in Northern China. Agriculture, Ecosystems & Environment 59, 223–231.