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A Review on Global Pesticide Use and Food Contamination: African Perspective

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ABSTRACT

Pesticide application has increased globally with increasing demand for food, and modernized Agriculture as a result of an explosion in the world's population growth, especially in developing nations in Africa, Asia, and South America. However, pesticides have helped to improve productivity, protect the nutritive integrity of food crops, and ensure year-round food supplies worldwide. The production and consumption of pesticides persisted from one decade to another until the ecosystem started to suffer from its adverse effects on the environment and human health. Previous investigations revealed that pesticides found entry into the human food chain. In response to these problems, researchers all over the world have conducted several kinds of research on pesticide applications, and their residual contamination in food. This review crosses from the past to present researches on the usage of pesticides, their accumulation in food, and possible methods of their reduction as highlighted by researchers over many years. There is a need for continuous monitoring of pesticide residue profile in soil, crop produce, and animal products in developing countries so that it will not exceed maximum residue limits (MRLs).

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INTRODUCTION

Regardless of a person's economic, social, or traditional background, having access to healthy food is a fundamental human right (FAO, 2009). To ensure food supply for the rapidly growing human population, which is projected to reach 9.7 billion in 2050 and 10.4 billion in 2100 (United Nations, 2019; Ezeh *et al*., 2022; United Nations, 2022), It is strongly anticipated that the agricultural industry would experience tremendous growth in the next decades. More than half of the projected increase in global population up to 2050 will be concentrated in just eight countries of the world: the Democratic Republic of the Congo, Egypt, Ethiopia, India, Nigeria, Pakistan, the Philippines, and the United Republic of Tanzania. Desperate growth rates among the world's largest countries will re-order their ranking by size (Alkema *et al*., 2020; United Nations, 2022). The 46 least developing countries are among the fastest-growing economies in the world. The population of many is expected to quadruple between 2022 and 2050, placing additional strain on resources and making it more difficult to

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fulfill the Sustainable Development Goals (SDGs) (Chao, 2022; United Nations, 2022; Ezeh *et al*., 2022).

Specifically, throughout the following ten years, to fulfill the nutritional needs of the world's expanding population, the agricultural sector needs to boost production by 15% (OECD-FAO, 2019, Frezal *et al.,* 2020). And by 2050, it is projected that a 50% increase will be necessary (FAO, 2017; United Nations, 2019; United Nations, 2022). And for this to happen, the application of various agrochemicals such as pesticides and fertilizer is going to play a major role. In this context, it is clear that the agro-food industry is at a turning point, with sustainability through an efficient and effective agrochemicals application to boast production with the ultimate objective to provide healthy food crops to the fast-growing world's population (Squatrito *et al*., 2020). Present-day agricultural practices should aim at supplying the world's expanding population with healthy and quality food while minimizing the adverse effects of agrochemicals such as pesticides on the environment, people, and producers' bottom lines (UCDavis, 2021).

Integrated pest management (IPM) system in Agricultural addresses environmental, economic, and social challenges related to pest management in food crop farming and storage (Binder *et al*., 2010; Pham and Smith, 2014; de Olde *et al*., 2017). It entails carefully weighing all available pest management methods before incorporating the necessary controls to prevent the spread of pest populations. In order to develop healthy crops with the least amount of pesticide application and to lessen the hazards that pesticides bring to human health and the environment, integrated pest management integrates biological, chemical, physical, and crop-specific (cultural) management tactics and practices. Integrated pest management is also a dynamic process that employs an ecological systems perspective that encourages the user or producer to take into account and use the complete range of optimal pest control solutions available taking into account economic, environmental, and social factors. The foundation of IPM is ecology, the idea of ecosystems, and the desire to maintain ecological services. It promotes natural pest management mechanisms and the growth of a healthy crop with the least amount of interruption to agroecosystems (Elkahky *et al*., 2020; Vreysen *et al*., 2021).

The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) signed a memorandum of understanding with the United Nations (UN) and other relevant international organizations in 1985 to establish the "International Code of Conduct on Pesticide Management," an international code of ethics for the management of agrochemicals, in response to concerns about the trade and safe use of pesticides. The fundamental goal of the Code of Conduct is to preserve the environment from the negative effects of pesticides while maximizing the benefits of using pesticides to effectively control pests in agriculture and public health. The Code of Conduct is designed for usage in accordance with national laws. As in addition to the statutory instruments on chemicals management, it describes the shared responsibility of many sectors, addresses the need for cooperation, acknowledges the need for capacity-building for its implementation, and describes the standards of conduct for pesticide management. (FAO, 1985; FAO-WHO, 2014). However, its adaption in the home country ranges from the stringent regulatory framework in the European Union (EU) to the considerably looser framework in developing countries. Many countries have been reported to adhere to this ethical Code scrupulously (Phillips, 2018; WHO-FAO, 2019; EUROSTAT, 2021b). Additionally, 65% of the countries do not forbid or restrict the use of highly dangerous pesticides, according to a recent study performed jointly by the WHO and FAO (WHO-FAO, 2019). The same source revealed that there are significant issues with pesticide registration procedures, uses, and management throughout Africa. Additionally, there is the issue of accumulating outdated and expired pesticides that are brought back from developed countries for safe disposal, like in the East Africa Rift zone (Lan *et al*., 2019), for example, the issue of the buildup of outdated and expired pesticides that are sent back to industrialized nations for proper disposal (Loha *et al*., 2018; Kosubová *et al*., 2020). The regulation on Maximum Residue Levels (MRLs) and import tolerances, as

Implemented by the European Union. For example, can ensure that the agricultural products fulfill the appropriate safety criteria.

when concerns about the impact of pesticide use center on whether the food is safe for consumers (Eurofins agroscience services, 2018; EUROSTAT, 2021a). Insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth hormones, regulators, and other agricultural compounds are classified as pesticides and are used to protect crops against illnesses and pests that could harm them (Guler *et al*., 2010; Ahoudi et al.,2018; Housseni *et al*., 2018). Although many pesticides are hazardous, toxicity and classification are dependent on the chemical constituents (Ecobichon,2001d; Wang *et al*., 2018; Akoto *et al*., 2013; Maksymiv, 2015; Andert *et al*., 2016; Nicolopoulou, 2016). According to previous studies from Clarke *et al.,* (2005), WHO-FAO (2018), Tolera (2020), Hedlund *et al*., (2020), herbicides (42.48%) are used and applied the most globally, followed by insecticides (25.57%), fungicides (24.19%), and other (7.76%). The benefits of using pesticides have been widely documented in the literature, and include a considerable decrease in yield loss in a variety of patterns and ways, and a decrease in insect pests on crops (Ecobichon, 2000a, Ochieng *et al*., 2013; Donkor *et al*., 2016; Housseni *et al*., 2019; Tolera, 2020). Pesticide plays a fundamental role in reducing crop yield losses and stabilizing the supply of agricultural products (Salazar and Rand, 2020; Sun *et al*., 2019). And the use of pesticides has been identified in the literature as one of the major agricultural breakthroughs in various emerging continents, including Africa (Hruska and Corriols, 2002; Mancini *et al*., 2005; Ngowi *et al*., 2007; Oluwole and Cheke, 2009; John et al., 2017; Ajmer *et al*., 2017; Anket *et al*., 2019; Lykogianni *et al*., 2021). Due to factors like ignorance, illiteracy, and insufficient training, many farmers apply pesticides

Blindly, with only about one-third of users taking into account the written instructions (Kumari, *et al*., 2013; Tsimbiri *et al*., 2015; Pouokam, 2019). This has led to issues with the environment and public health (Aktar *et al*., 2009; Adjrah *et al*., 2013; Kumari and Reddy, 2013; Banerjee *et al*., 2014; Mahmood *et al*., 2016; Imane *et al*., 2016). More than 95% of the time, pesticides are administered to unintended locations, like food plants (Cooper and Dobson, 2007; Oluyede and Festus, 2007; Jean-Pierre and Pascal, 2009; Barchaska and Baranowska, 2009). The main source of pesticide residue contamination in food plants is the direct application of pesticides to growing plants, with a little input from pesticide residue in the soil where they are applied (Darko and Akoto, 2008a; Bempah *et al*., 2011a; Ogah *et al*., 2011). It is well known that contaminated food items can harm the Immune system in humans who consume them (Carson,1962, HSDB, 2018; SánchezGuerra *et al*., 2013), which is brought on by an increase in the daily diet intakes of chemicals from the contaminated food crop (Ecobichon 2001b; Nasreddine and ParentMassin 2002; Stenersen 2004; Yazgan *et al*. 2000). Consequently upon these negative developments arising from various pesticide malpractices and its adverse effect on our ecosystem, the researchers' goal of this review is to explain the distribution of Pesticide use, its market distribution in the world with Africa as a focus, residue occurrence in some food crops and finally the best ways to ameliorate the problem, particularly in African countries.

Global pesticide use

Dichlorodiphenyltrichloroethane (DDT), which was created by a German scientist named Ziedler in 1873 and whose insecticidal properties were accidentally discovered by a Swiss chemist named Paul Muller in 1939, was the first and most significant synthetic organic pesticide. DDT's broad-spectrum activity, persistence, insolubility, low cost, and ease of usage were once lauded as magical qualities (Keneth, 1992). Particularly p,p'-dichlorodiphenyltrichloroethane (ddt)was such an efficient pesticide that it increased agricultural yields and was so reasonably priced that its use swiftly expanded around the world. DDT was additionally applied in numerous non-agricultural settings. In World War II, for example, it was used to delouse soldiers, and it is employed in public health to eliminate mosquitoes, which are the carriers of malaria. Following the effectiveness of DDT applications, new chemicals were created, resulting in the era that Rachel Carson (1962) referred to as the "shower of chemicals" in her book "The Silent Spring." The "green revolution" and the extensive usage of pesticides in agriculture are both well known. The Green Revolution was an agricultural movement that spread throughout the globe and started in Mexico in 1944. Its main objective was to increase grain yields in a world that already struggled to provide enough food to feed its fast-growing population. The use of pesticides and other agrochemicals was one of three key parts of agricultural techniques that were involved in the "green revolution." Between 1990 and 2007, the use of pesticides increased on its own, but after that, there was a tendency to decline. Pesticide use worldwide has been estimated to increase up to 3.5 million tonnes and the numbers are rising steadily. (FAO/WHO 2002; WenJun, 2018; Sharma *et al.*, 2019; Leong *et al.*, 2020; Mojiri *et al.*, 2020; Tang, 2021). Roughly 45% of the overall consumption is readily used by European countries while approximately 25% of the remaining is used in the USA and the rest by the rest of the globe, (Ritter, 1990; De *et al.*, 2014; Dubus *et al.*, 2020). One of the biggest issues in the agricultural sector is insect pests. According to the Food and Agricultural Organization (FAO), these pests reduce crop yield globally by 20 to 40 percent yearly (Mohamed *et al.*, 2021). Each year, insects and pest infestations together cost the world economy some $220 billion and invasive insects around US$70 billion annually (Mohamed *et al.*, 2021).The following analysis breaks down the global pesticide market by pesticide type: herbicides (50 %), insecticides (30 %), fungicides (18 %), and other types such as rodenticides and nematicides (2 %) (WHO-FAO, 2018; Sharma *et al.*, 2019). In addition, between 1990 and 2019, the average amount of pesticides used per acre in Africa increased from 0.32 kg to 0.39 kg (FAO, 2021). According to estimates, pesticides are used in the production of close to one-third of agricultural products (Liu *et al.*, 2002; Zhang *et al.*, 2011). The volume at which pesticides are being utilized is quickly growing due to the perception that pesticides can reduce harvest uncertainty. Besides, purchases of insecticide are made by both large and small manufacturers, and, subsidies for pesticides have become less common in most developing countries since the 1990s, due to a combination of structural adjustment policies and emerging sustainability thinking. Currently, around two million tonnes are used per year on a global scale, most of which are herbicides followed by insecticides, fungicides, and other types such as rodenticides and nematicides (Sharma *et al.*, 2019). Globally, a total of approximately 9000 species of insects and mites, 50000 species of plant pathogens, and 8000 species of weeds injure crops (Zhang *et al.*, 2011), of which insect pests caused an estimated 14% of loss, plant pathogens caused the 13% loss, and weeds the 13% loss (Pimentel, 2009). According to estimates, pesticides are used in the production of close to one-third of agricultural products (Liu *et al.*, 2002; Zhang *et al.*, 2011; Lasley *et al.*, 1990). Without the use of pesticides, losses from insect damage to fruits, and vegetables (Mishra *et al.*, 2014; Leong et al., 2020), and cereals might reach 78%, 54%, and 32%, respectively (Cai, 2008). Using insecticides reduced crop loss due to pests by 35% to 42%. (Pimentel, 1997). In the USA, fungicides were used on 80% of the fruit and vegetable crops. The use of fungicides was predicted to improve the commercial worth of apples by 1223 million US dollars (Guo *et al.*, 2007). Without pesticides, cotton, wheat, and soybean exports from the United States would decrease by 27%. (Mancini *et al.*, 2005; Zhang *et al.*, 2011). Overuse of pesticides and pollution, however, has also increased (Carson, 1962; Pimentel, 2009; Liu *et al.*, 2008; Zhang and Liu, 2017). According to government data from 2016, Chinese farmers used pesticides at a rate that was three times higher than the global average (Fan, 2017) and according to a 2013 Greenpeace investigation, 70% of pesticides applied in China did not reach plants as intended and instead leaked into the groundwater and soil (Fan, 2017; Langenbach *et al.*, 2017).

Insecticide, rodenticide, and herbicide poisoning accounted for 7.16 %, 6.4 %, and 3.4 % of the overall cases of pesticide poisoning, respectively, according to Chen et al (Zhang *et al*., 2011). Highly toxic organophosphorus pesticides were the main cause of human poisonings, and they account for 86.02% of all cases (Zhang *et al*., 2011). In eastern China's Zhejiang province, between 2006 and 2015, approximately 3000 children were poisoned by pesticides, with the majority of instances occurring during the growing season, according to research published in June 2017 (Fan, 2017).

Global Pesticide Distribution

According to the website of the Swiss Journal Springer, 2 million tonnes of pesticides were distributed worldwide in 2019 (Globalnewswire, 2022). Of these, 47.5% were herbicides, 29.5% were insecticides, 17.5% were fungicides, and 5.5% were other pesticides as illustrated in Fig. 1.

Consequently, the market for pesticides is expanding as a result of the rising use of herbicides most especially organophosphorus compounds such as glyphosate to mention but a few. To maintain their market share, major companies engaged in the industry concentrate on developing new, innovative products such as nano pesticides (Sun *et al*., ^9019; Globalnewswire, 2022). Apart from the official record of Europe and the USA, 15% of banned pesticides are still produced and used in poor nations, such as DDT (Lowry and Frank, 1999; Ecobichon, 2001c; Kitowsk et al., 2020; Pinto *et al*., 2020; Wang et al., 2020; Kosubová et al., 2020; Sarkar *et al*., 2021; Wood Mackenzie, 1994). In terms of money, between 1960 and 1992, sales of pesticides on the global market increased by over 10% in developing nations (Lowry and Frank, 1999). Over 17 billion dollars of the $30 billion global pesticide market in 1995 came from only three countries: the United States, Western Europe, and Japan, with the bulk of developing countries, only contributing about 2 billion dollars annually (WRI, 1996). With $40.8 billion in commerce, pesticides were the 85th most traded good in the world in 2020. (OEC, 2020). Pesticide exports increased by 13.8% between 2019 and 2020, from $35.8 billion to $40.8 billion. Pesticide commerce makes up 0.24 percent of all trade in the globe (OEC, 2020). With an estimated export value of $7.62 billion in 2020, China was the world's top exporter of agricultural pesticides. The next three countries in order of export value were Germany, France, and the United States. Other nations include India, the United Kingdom, Spain, Israel, Belgium, and Italy, as seen in Fig. 2 (Statista, 2023). Around 15 billion dollars were spent annually in the United States to purchase active ingredients, which

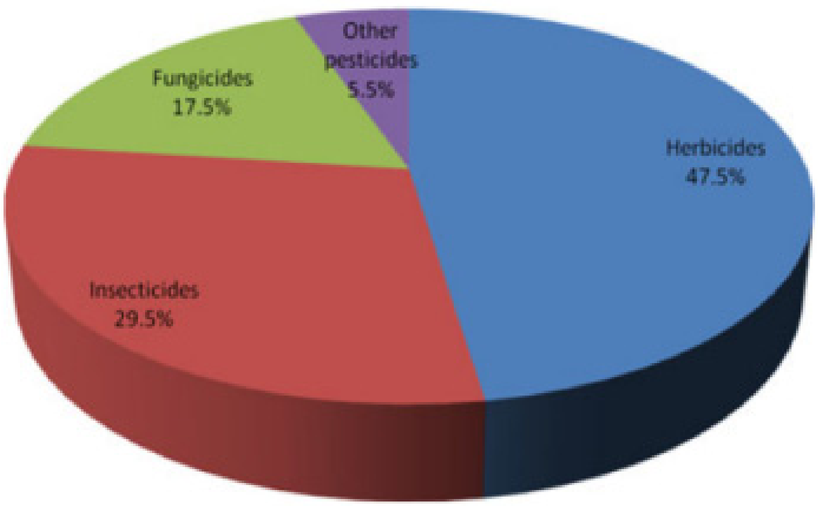

Fig. 1. Pesticides distribution at worldwide level in 2019 (Globalnewswire, 2022)

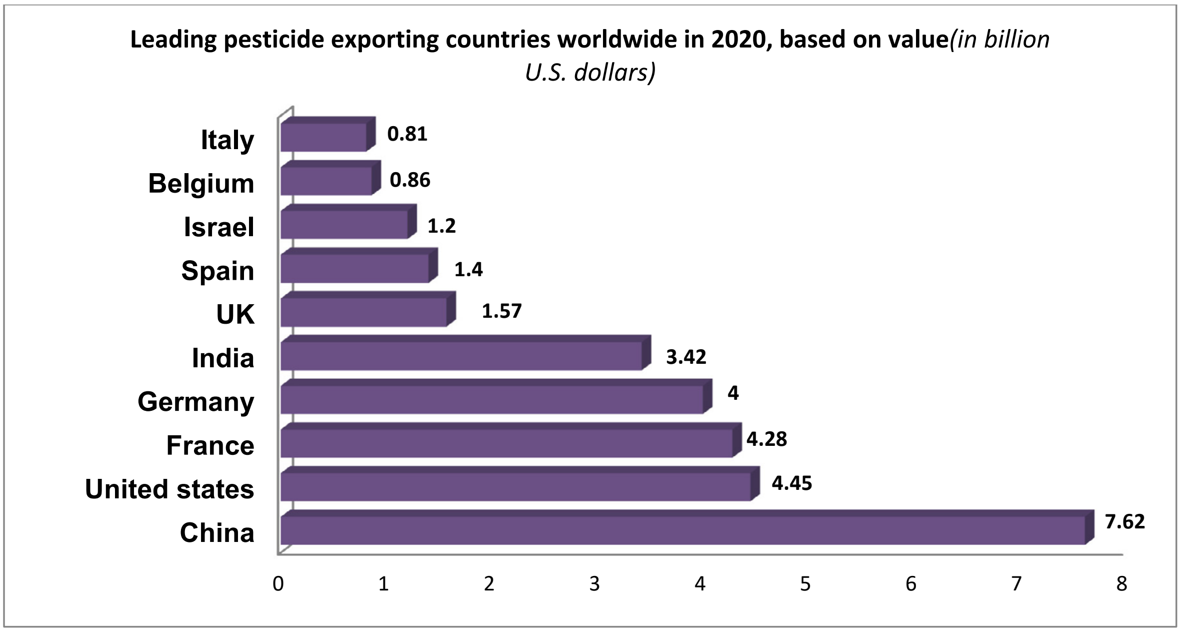

Fig. 2. Leading pesticides exporting countries in the year 2020 (Statista, 2023)

is equivalent to about 55% of the entire amount in the global market (Dalaker and Naifeh, 1998; Intelligence, 2018). The global pesticide market is expected to grow from $78.16 billion in 2021 to $85.11 billion in 2022 at a compound annual growth rate (CAGR) of 8.9% (Globenewswire, 2022). The pesticides market is expected to grow to $105.39 billion in 2026 at a CAGR of 5.5% (Globenewswire, 2022). The pesticides market's largest region in 2021 was Asia-Pacific. Asia-Pacific, Western Europe, Eastern Europe, North America, South America, the Middle East, and Africa are the areas covered in the pesticide market study (Globenewswire, 2022). The United States of America, France, India, Germany, and Mainland China are the top 5 countries that export pesticides to other countries. This group of significant suppliers accounted for 58.5% of all pesticide export sales made abroad in 2021 (Worldtopexport, 2022). With shipments valued at $19.1 billion, or 43.5% of the global total, European nations had the most foreign sales from pesticide exports among all continents in 2021. At 39.1%, Asian exporters came in second, and 12% of pesticide shipments worldwide came from North America (Worldtopexport, 2022). A record of over 1.5 billion dollars' worth of pesticides has previously been imported into Africa from China, after being initially imported from European nations from the exportation and importation perspectives (Forget, 1991; Smith and Root, 1999; Wandiga, 2001; Haylamicheal and Dalvie, 2009; Wilson and Otsuki, 2004; Haylamicheal, and Dalvie, 2009; Loha *et al*., 2018; Kuchheuser *et al*., 2022). According to FAOSTAT data, China has an expanding market for exporting pesticides, with forty-four African nations receiving 14% of the exports, which total 300,000 tons annually (Yu *et al*., 2020; Zhao and Pei, 2012;Shattuck, 2021; Pan and Luning, 2021; Sarkar *et al*., 2021).

Thousands of pesticides are imported by China; Table 1 lists the top 10 formulation items and active components by number of imports.

The top 10 pesticides that are most frequently imported are primarily herbicides, followed by the next 10 chemical formulations that are primarily insecticides (chlorpyrifos, dichlorvos, dimethoate, abamectin, and cypermethrin). It should be mentioned that before being imported, pesticide products virtually universally require homologation and authorization (USAID, 2017). Additionally, users are given information about the product's intended uses, dosage, toxicological classes, first aid procedures to be followed in the event of exposure, and even an antidote in the event of ingestion. Despite these safety measures, case of pesticide malpractice

Table 1. Top 10 of the most imported formulation products and active ingredients

Formulation products	Export value (million USD)	Export volume (000 tons)
Glyphosate IPA 41% SL	93.82	50.82
Paraquat 200 g/L SL	62.53	25.97
Glyphosate 30%	20.07	10.44
Lambda-cyhalothrin 25 g/L EC	16.97	5.68
Mancozeb 80% WP	16.69	5.08
Glyphosate-monoammonium 75.7% SG	16.33	4.84
2,4-D-dimethylammonium 720 g/L SL	14.78	7.29
Mancozeb 64% + Metalaxyl 8% WP	11.61	1.80
Atrazine 80% WP	10.19	3. 13
Imidacloprid 20% SL	8. 13	1.91
Total	271.12	111.69

Source: Bertrand, 2019

is increasing yearly (Pouokam, *et al*., 2017, USAID, 2017).

Africa pesticide use

Nigeria, South Africa, Ghana, Ivory Coast, Egypt, Kenya, Cameroon, Tanzania, Ethiopia, and Guinea are the top 10 nations in Africa that import pesticides, accounting for nearly 86% of the continent's total value. The top 10 pesticides on this list are listed in Table 1.0 (Donkor *et al*., 2016, Haggblade and Diarra, 2017, Loha *et al*., 2018, Bertrand, 2019, ElSafoury, 2020, Veludo *et al.*, 2022, Degrendele *et al*., 2022, Kuchheuser and Birringer, 2022; Quinn *et al*., 2011; Ogada, 2014). These importations have ultimately contributed to an ongoing rise in pesticide use, which has climbed by almost 200 percent in only the past ten years (2000 – 2010) (Quinn *et al*., 2017; Thompson *et al*., 2017; Ecobichon, 2001b; Williamson, 2003). According to official records, Africa utilized 70,000 active ingredients from pesticides between 1990 and 2016, accounting for 3% of global usage during that time (Olisha *et al*., 2020; Sibanda *et al*., 2000; Vaissayre and Cauquil, 2000; Conway, 2013). Unfortunately, few imported products are labeled and registered, and many of these lack a set amount or percentage of active components (Fishel, 2010; Grube *et al.*, 2011; Utembe and Gulumian, 2015; Ridolfi *et al*., 2018; Sarkar *et al*., 2021; Obeten *et al*., 2022).

The WHO added them to the WHO risk categorization of pesticides after taking into account the situation and circumstances surrounding these pesticide importations, in addition to the farmers' ignorance of the usage, dosage, and toxicity of both the marked and unlabeled pesticides in Africa (WHO, 1990; WHO, 2002; Thundiyil, *et al*., 2008; Yadav and Devi, 2017; Loha *et al*., 2018; WHO, 2020). However, the policy effort claimed that various factors, including biological, economic, and climatic considerations, affect how much of Africa is used (Lasley *et al*., 1990; Mudimu *et al*., 1995; Ngowi, 2002; Gao *et al*., 2013; Khalid *et al*., 2020).

In Africa, synthetic pesticides have been used for more than 80 years. They were most likely brought to the continent by former colonial rulers (FAOSAT, 2018). From a historical perspective, the Public Health Act of the British government legislation was passed in 1921 to safeguard people and control the use of pesticides by farmers in Kenya (Wandiga, 2001). Since then and up until the present, African nations have continued to buy pesticides from nations with more developed economies, primarily from European nations and more recently from China (FAOSTAT, 2017). According to Regulation (EC) No. 1107/2009 and Regulation (EC) No. 396/2005, several pesticides are prohibited or limited within the EU because of their detrimental effects (European Commission, 2019). However, pesticide businesses with headquarters in the EU export significant quantities of pesticides that are prohibited for use in the Union to poorer nations whose usage laws are less stringent. The year 2018 saw the shipment of 81 615 tonnes of pesticides that were prohibited for use within the EU by companies. An examination by Non-governmental organizations (NGOs) that gathered information from the European Chemicals Agency and regulators in Belgium, France, the United Kingdom, and Germany revealed that more than half, 42 636 tonnes, would travel to developing nations (Unearthed and Public Eye 2020); Brazil, Mexico, Indonesia, Malaysia, Colombia, Peru, South Africa, the Russian Federation, Morocco, India, Chile, Honduras, Vietnam, Ecuador, Egypt, Thailand, Cuba, Turkey, and Guatemala rounded out the top twenty travel destinations. According to FAO statistical (FAOSTA) database, Africa imported an estimated 1.6million USD worth of pesticides in the recent years (FAOSTAT, 2017, Erwin, 2018, FAOSAT, 2018, FAO/WHO/CODEX, 2020). However, over the past decades, pesticides importation from China is growing constantly. According to export data published by China Customs and shown in Figures 2 and 44 various countries, African markets accounted for 13.9% of total pesticide exports from China between January and November 2015. (Erwin, 2015). The health safety (H) codes 29 and 38 were used for the export of these pesticides. The top 10 importing countries by value are Nigeria, Egypt, Ivory Coast, Tunisia, Morocco, Zambia,Uganda, and Zimbabwe South. These top 10 nations account for 85.9% of China's total exports to Africa in terms of export *value (*Figure 3*).*

Negative effects on biodiversity

More than 90% of the 107 major crops in the world are pollinated by more than 20,000 species of bees (Harvard School of Public Health, 2015). They have experienced a dramatic decline in population over the past few decades due to anthropogenic activity, particularly the use of pesticides and other agrochemicals in farming systems and the environment (Harvard School of Public Health, 2015). According to recent studies, hazardous insecticides, particularly neonicotinoids like acetamiprid, clothianidin, imidacloprid, thiacloprid, and thiamethoxam,

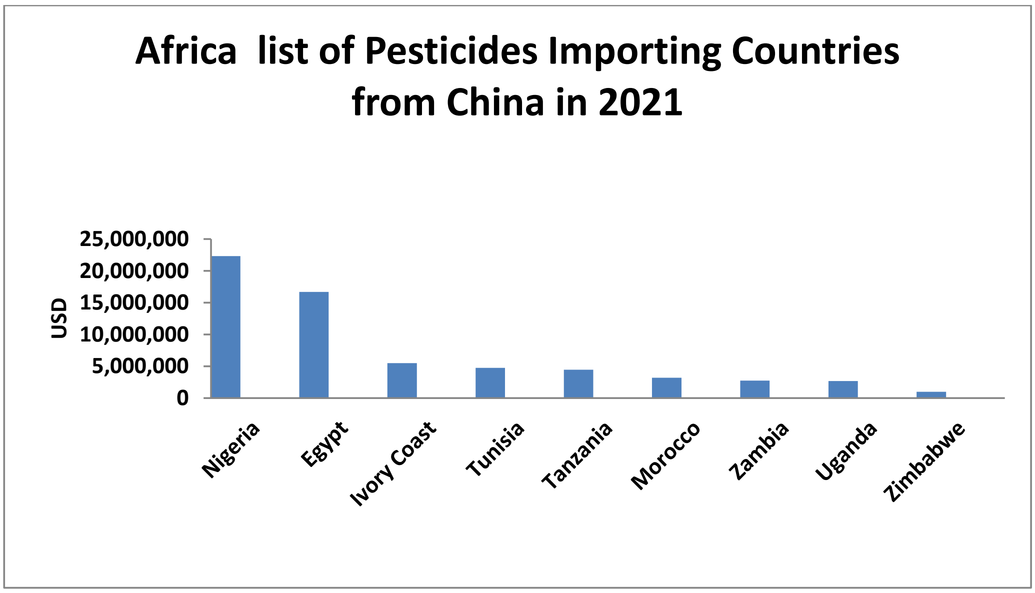

Fig. 3. Top ten importers of pesticides from China by import value (Worldstopexport, 2021)

have contaminated 75% of the world's honey (Harvard School of Public Health, 2015; Sheridan *et al*., 2017; Maksymiv, 2015). Possible loss of biodiversity as a result of widespread pesticide use (Kumar *et al*., 2013; Zhang *et al*., 2011; Mahmood *et al*., 2016). Unfortunately, it was found that neonicotinoids have been recognized as a significant factor in the global drop in bee population (Harvard School of Public Health, 2015). Some reports claim that the usage of pesticides may be to blame for the global extinction of some insect species or the collapse of insect populations (Sánchez-Bayo & Wyckhuys, 2019; Brühl *et al*., ^9019; Goulson, and van derSluijs, 2019). The insect population in the Orbroicher Bruch nature reserve has decreased by 78%, according to a recent report by scientists at Radboud University Nijmegen and the Entomological Society Krefeld who looked into other insect species and abundance in more than 100 nature reserves throughout Western Europe since the 1980s. According to a study, hoverflies had 143 species in 1989 and 104 species in 2014. (Jin, 2017).

Health implications of Pesticides on humans

Chemical pesticides, especially those that contain chlorinated chemicals, can be hazardous to humans and are frequently persistent in the environment. These pesticides are harmful to a wide variety of life forms, and their effects can have an even wider reach than the area where they are produced and applied If agricultural workers do not wear the appropriate protective equipment, direct inhalation, and skin contact with chemical pesticides can be harmful to them, dangerous for adjacent people, and even fatal (Marquis, 2013). Most farmers in developing nations lack formal education and lack knowledge about safe chemical handling practices. Farmers' health may suffer as a result of the improper handling, application, and interaction of these agrochemicals (Marquis, 2013). Ingestion of contaminated foods, ingestion of contaminated soil, especially in children who may not wash their hands before eating after playing with contaminated soil (Marquis, 2013), contamination may also occur by use of pesticides containers as domestic water and food storage cans as observed among local farmers in developing countries (Longnecker *et al*., 1997), and contamination are all common pathways for human exposure to pesticides (Longnecker *et al*., 1997). However, the problem of food safety and health danger has persisted due to the ongoing and careless use of pesticides (Erhunmwunse *et al*., 2012, Carvalho, 2017). Persistent Organic Pollutants (POPs) are a family of chemicals that include many of the most commonly used pesticides. POPs have lengthy half-lives, poor biodegradation rates, and the capacity to bio-accumulate in living tissue. Large concentrations of pesticides can contaminate the entire food chain when they accumulate in food sources (Nicolopoulou-Stamati *et al*., 2016). Humans are extremely concerned about food safety. To lessen the risk to human health from pesticide residue and its metabolites, careful handling and use must be used to limit human exposure and contact, especially through the food chain (Nicolopoulou-Stamati et al., 2016). Pesticides are intentionally released into the environment through agricultural practices and environmental cleanliness, in contrast to other pollutants. Despite the use of good agricultural practices (GAP), some crops produced on pesticide-treated soils may contain residual levels of the pesticides or their metabolite(s) (Zabaloy, 2011). Organochlorine and organophosphate pesticides, such as dichlorodiphenyltrichloroethane (DDT), glyphosate, and methoxychlor, in particular, adsorb heavily to soils and have a high potential to remain unavailable to microorganisms for biodegradation (Gilden *et al*., 2010; Vargas -Bernal *et al*., 2012). In addition, regular pesticide use can result in chemical overload on agricultural soils and, as a result, the plant's uptake of the pesticides under favorable conditions. Additionally, pesticide leachate finds its way into groundwater or other bodies of water, posing a serious risk to aquatic life, animals, and people who consume it (Mojiri *et al*., 2020). According to the World Health Organization, three million farmers in developing countries are thought to be acutely poisoned by pesticides each year, resulting in 18,000 deaths (Zabaloy, 2011). Numerous studies have been done that indicate pesticide exposure may raise the likelihood of developing diseases including Parkinson's disease, cancer, and male infertility, to name a few. Organochlorines, organophosphates, and carbamates, as well as other insecticides and herbicides, have been linked in a small number of research on pesticide exposure and the risk of Parkinson's disease (Vegucht *et al*., 2006). Organochlorine insecticides, such as beta-hexachlorohexane (-HCH), are neurotoxic, create oxidative stress, and harm the brain's dopaminergic system, according to animal toxicological tests (Vegucht *et al*., 2006). Human exposure to Pesticides can cause human fecundity and affect the intelligence quotient causing many human and animal disorders (Chen *et al*., 2004; Zhang et al., 2011; Zhang, 2018). Additional research has demonstrated a connection between Parkinson's and Alzheimer's disease and exposure to HCH (Vegucht *et al*., 2006). More specifically, multiple case-control studies have found an association between pesticide exposure and an elevated incidence of Parkinson's disease (Pezzoli *et al*., 2013). Reports have described Parkinson's disease in people exposed to organophosphates, paraquat, diquat, maneb, and other ethylene bisdithiocarbamates in addition to analytical investigations (Vegucht *et al*., 2006). Compared to individuals with other neurological disorders, Parkinson's disease patients' post-mortem brains have higher levels of organochlorine residues, particularly dieldrin (Pezzoli *et al.,* 2013). Because they might change how hormone systems work and have negative health consequences on people, some pesticides are considered to be endocrine disruptors (Vergucht *et al*., 2006). By imitating the actions of natural hormones, preventing their normal function, or interfering with the biosynthesis or removal of hormones, they lead to toxicity (Aktar *et al*., 2009). The effects of oestrogen can be mimicked by several substances, including pesticides and organic plant products. Endocrine imbalance frequently causes cancer, infertility, reproductive problems, and sexual abnormalities (Gupta, 2011). More specifically, genital abnormalities, testicular cancer, and some types of worse sperm quality can occur at an early age or even when the fetus is still developing (Cox, 1996). Although pesticides have played a significant role in the expansion of agriculture worldwide, they frequently affect species other than those they are intended to kill. Organophosphate and organochlorine pesticides, for instance, can affect neurological systems by damaging neurotransmitting enzymes and can be consumed by a variety of species, according to Longnecker et al. (1997).

Existing regulation

Regulation 149/2008/EEC, a provision of European Union legislation regulating maximum residue levels (MRLs) for pesticides, went into force in September 2008 (Morner *et al*., 2002). The regulation established a maximum limit on the number of pesticides that were permitted on imported commodities, including grains. As a result, starting in September 2008, all food crops imported into the EU must comply with the new Regulation (Olufade *et al*., 2014; Isegbe et al., 2016). The Food Quality Protection Act of 1996, which was developed in the United States by the Environmental Protection Agency (EPA), governs the number of pesticide residues that are allowed on food that is intended for human consumption. The EPA additionally mandates that any pesticides that have been approved be clearly labeled with directions for safe use, handling, storage, and disposal. A new law in Japan that established new MRLs for food products was established by the Ministry of Health, Labor, and Welfare (MHLW) and went into effect in May 2006. In Nigeria, it is mandated that the Standard Organization (SON) and the National Agency for Food and Drug Administration and Control (NAFDAC) regulate and control the manufacturing, importation, and distribution of agrochemical-based chemicals like pesticides (Keri, 2009).

Influencing factors for pesticides occurrence in consumable food

The influencing factors are more associated with the different reasons for different countries depending on the agricultural activities that take place there (In *et al*., 2006; Ghimire and Woodward, 2013; Farha *et al*., 2016; Zhang et al., 2020). Although there are general causes that will be mentioned in this review. The major general cause of the continuous occurrence of pesticides and their residue is the wrong dosage application which comes about as a result of ignorance of the specification and standard in the application (Hall and Norgaard, 1973; Matthews, 1999; Stoytcheva, 2011). Another factor noted by researchers is the use of banned pesticides because they are most cost-effective and easily affordable (Brun *et al*., 2008; Fantke *et al*., 2012; Davis, 2014; Ruiz-Suárez *et al*., 2015). The amount and nature of the pesticide applied are also the reason that can influence its persistence to remain in the food after its application to eradicate pests (Pimentel *et al*., 1992; Gammie, 1994; Wilson and Tisdell 2001; Lan *et al*., 2019). Furthermore, environmental and climatic factors such as rainfall, wind, and sunshine can also trigger the potential of the pesticide to remain in food (Rice et al., 2007; Fishel and Ferrell, 2010; Delcour *et al*., 2015; Langenbach *et al*., 2017; Andrade *et al*., 2021).

Food grains

Since it has been discovered that grains are quickly attacked by pests, pesticides (often biodegradable forms) are used to reduce grain loss, accomplish optimal storage, and preserve seeds for future planting (Guo-Fang *et al*., 1999; Collins, 2006; Vela *et al*., 2007; Selvaraj *et al*., 2014; Oyeyiola *et al*., 2017; Mahugija *et al*., ^9017; Koli and Bhardwaj. 2018). The rate of pesticide degradation, the state of the storage environment and facility, and the pesticide's potential health effects, particularly if it is applied after harvest, all affect the selectivity of pesticides used to store grains (Osibanjo and Adeyeye, 1995; Abou *et al*., 2010; Avancini *et al*., 2013; Rusu *et al*., 2016; Kova *et al*., 2021; Nyarko *et al*., 2021). For instance, it has been established that some pesticide applications are applied as an exterior layer whereas others, like deltamethrin, penetrate the grains (Savi *et al*., 2015; Kovač *et al*., 2021). FAO and WHO established pesticide residue limits for pesticides used in the post-harvest of grains for the safety of seeds and consumptions in consideration of the ongoing use of pesticides and consumer health (Holland *et al*., 1994; UNEP *et a*l., 1988; Amenze *et al*., 2014; Mahugija *et al*., 2017; Crépet *et al*., 2021). Different types of pesticide residual content have been identified in various grains, including rice, according to research (Saka *et al*., 2008; Pareja *et al.,* 2011; Min, *et al*., 2012; Arora, *et al*., 2014; Beans (Bakore *et al*., 2004; Szentpétery *et al*., 2005; Dalvie and London, 2009; Guler *et al*., 2010; Fantke *et al*., 2011; Medina, *et al*., ^9021); wheat (Huang *et al*., 2015; Asiah *et al*., 2019; Gwary *et al*., 2011; Ogah *et al*., 2012; Oyekunle *et al*., 2017; Otitoju, and Lewis, 2021), Thompson and Hill (1969), Wicker et al. (1979), Do *et al*. (2010), Avuthu *et al*. (2016), Nyarko *et al*. (2017), maize, (Ogar *et al*., 2011).

Fruit

The application of pesticide in fruit farming is mainly to reduce toxin that is secreted by pest into the fruits which eventually leads to spoilage causing loss of productivity and making labor stressful with little or no profitability gain (Torres et al., 1996; Cabras et al., 1998; Knežević and Serdar, 2009; Chen *et al.,* 2011; Chung, 2018). Literature has established pesticide residue in a different fruit. Examples include cucumber (Safi *et al*., 2002; Liang, *et al*., 2012; Zou *et al*., 2017; Golge *et al*., 2018), Oranges (Valenzuela *et al*., 2001; Fernandez *et al*., 2001; Blasco *et al*., 2006; Nakano *et a*l., 2016; Suárez-Jacobo *et al*., 2017), apples (Štěpán *et al*., 2005; Kong *et al*., ^9012; Mladenova *et al*., ^9009; Ticha *et al*., 2008; Mladenova and Shtereva, 2009; Kong *et al*., 2012; El Hawari *et al.,* 2019), cabbage (Patel *et al*., 1999; Chen *et al*., 2011; Zhang *et al*., 2007), mangoes (Hussain *et al*., 2002; Ciscato *et al*., 2009; Phan *et al*., 2018; Farooq *et al*., 2019).

Milk, cheese, butter, and meats

Many researchers have also proven that milk, butter, and cheese can also be contaminated by pesticides by having pesticide residue in them (Maitre *et al*., 1994; John *et al*., 2001;

Salas *et al*., 2003; Kuang, *et al*., ^9020; NagandRaikwar, 2008; Akhtar and Ahad, 2017; Kuang *et al*., 2020). The study showed that they are contaminated through the feeding of the animals that produced them, most especially when they feed on grasses spayed with pesticides which explains the reason for the contamination of cheese, butter, and all kinds of product of milk (Mallatou *et al*., 1997; Nag *et al*., ^9008; Darko and Acquaah, 2008b; Kaushik *et al.,* 2009; Bajwa, and Sandhu, 2014**;** Duan *et al*., 2018). Furthermore, it has been gathered from the literature that Pesticides residue targets the fatty part of the animals for preferential concentration than other parts also concentrate preferentially in the fatty portions of meat (Johnson et al., 1976; Hashemy-Tonkabony *et a*l., 1981; Tekel *et al*., 2001; Choudhary *et al*., 2018). The consumption of these agri-products directly brings about the ingestion of pesticides and their attendant implication on the consumer (Saucier, 1999; Darko and Acquaah, 2007, Jadhav and Waskar, 2011).

Reduction of pesticides in food

Different suggestion has been given for the reduction of pesticides in consumable foods and the main point will be reviewed. This reduction in pesticide residue become necessary due to the rejection and ban of some Nigerian grains by European countries as reported In the Nigeria editorial newspaper. As a result, many scholars opinioned that the use of certain or all pesticides should be discouraged amidst non-organic food plants after it has been discovered to have four times more accumulation than organic foods (Curl *et al*., 2003; Smith-Spangler, 2012; Del *et al*., 2013; Wahlqvist, 2013; Baranski *et al*., 2014; del Mar *et al*., 2020). Secondly, since some of the pesticides reside mostly on the surfaces of fruit, washing with water or chemicals could be a possible solution to some of them (Yoshida *et al*., 1992; Bull, 1992; Al-Taher *et al*., 2013; Holland *et al.*, 1994; Celik, 1995; Keikotlhaile et al., 2010; Andrade *et al*., 2015; Chung 2018; González-Alzaga *et al*., 2020). Thirdly, processing procedures used such as peeling or cooking could reduce it (Rano and Singh, 2021; Mir *et al*., 2021; Medina *et al.,* 2021; Ishfaq *et al*., 2022). Literature has also established that cooking can reduce about 60% of pesticides residual while similarly, husking has also proved to be a possible solution (Posser and Halt, 2005, Srinivasan, 2019). Sun *et al*. (2019) recommend using of nano pesticides in agriculture to prevent pests also aimed at preventing negative effects on biodiversity, reducing bioaccumulation of pesticide residue in food crops, and having high biological activities, effective and efficient target, and non-target organisms systems, and better and efficient penetrating systems with low dosage. Besides, allowing lag time to pass before taking food crops to market after insecticide application for instance will reduce pesticides in our food considerably. In addition, biopesticides should be considered, as a supplement to traditional pest control methods rather than a substitute. Currently, 5% of crop protection chemicals sold are biopesticides (Baylis, 2020). However, the question of why and how more biopesticides cannot be made commercially available arises. The solution depends on resolving challenges with fermentation and formulation, scale-up and mass production, shelf life, and interactions between policymakers, regulators, researchers, and the industry (Birch and Glare, 2020). Besides, the newest advancement in agrochemical development is nano pesticides. They are more effective pesticide products. They fall into two categories. Pesticides with nanoscale active components are the first category of nano-pesticides. This category of pesticides typically consists of nano dispersant/(micro) emulsion pesticides and powder pesticides [Chaw *et al*., ^9012; Debnath *et al*., ^9013). The second category of nano-pesticides includes pesticides that are coated directly with nanoparticles to create a "nano-coat," loaded with nanomaterials, doped in nanomaterials, or directly coated with nanomaterials. This type of pesticide typically contains nano-components that improve the performance of the original pesticides' effective components, target transportation, safeguard pesticides and regulate pesticide release (Atta *et al*., ^9015; Mohasedat *et al*., ^9018]. In comparison to conventional pesticides, nano-pesticides showed advantages including minimal volume utilization and great efficacy. Traditional pesticides are used on fewer than 30% of the crops that they are intended to target because of their coarse drug carrier particles, poor dispersibility, limited biological activity, and poor stability (Zhang *et al*., ^9018; Ocho *et al.,* ^9016). However, the more equally nano-pesticides are spread on crop leaves, the more effective they are, and the smaller their particle size is. The nano-carriers of pesticides can also increase the stability and dispersibility of pesticides while facilitating the delivery of the active ingredients to the intended targets to increase bioavailability (Mohasedat *et al*., ^9018; Ali *et al*., 2014; Sharma *et al*., 2017). These benefits could offset the drawbacks of traditional insecticides' high dosage and inefficient, impractical application.

Finally, there is a need for government advocacy programs in local areas geared toward the orientation and re-orientation of farmers on Integrated Pest Management (IPM) and good agricultural practices (Obeten *et al*., 2022).

CONCLUSION

Pesticide production has continually increased over the years because of higher agricultural activities taking new shapes and dimensions with the sole aim of feeding ever increasing world population. Although, some pesticides have been banned for their toxicity yet they are in circulation for their cost-effective implications. The use of pesticides ignorantly has resulted in their entry into the food chain and consequently into the consumers of such products. Having in mind that there are attendant health challenges resulting from their consumption, it is, therefore, necessary to take caution on the usage and consumption of contaminated products.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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