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ENVIRONMENT DIRECTORATE****Joint Working Party on Trade and Environment****New digital technologies to tackle trade in illegal pesticides**

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Key messages

- The growth of international trade in illegal pesticides poses a significant threat to agriculture, the environment, human health and the economy.
- Cracking down on these criminal activities has become more difficult due to growing pesticide trade flows and the increasing complexity of pesticide supply chains.
- Blockchain and other new digital technologies (e.g., big data, AI) hold significant promise for supporting the implementation of policy responses on traceability and authentication of pesticides, and the monitoring and control of pesticide trade.
- The wider adoption of these digital tools by supply chain actors and control agencies could significantly reduce the risks of entry and sale of illegal pesticides.
- The adoption of these emerging technologies can be challenging given the large upfront costs associated with IT development and infrastructure, and their complexity. This is especially true for developing countries.
- While digital-based solutions may allow for the identification of criminal activities, they are insufficient to address this issue. Other policy actions beyond those based on these technologies also need to be implemented (e.g., raising public awareness, increasing sanctions).

Executive summary

1. This paper explores the potential of blockchain technology – a digital distributed ledger system – to support the implementation of policy actions for tackling trade in illegal pesticides. Blockchain is usually used with other digital technologies – e.g., sensors for the creation of data, big data analytics, and artificial intelligence – hence the complementarity of these technologies with blockchain is also discussed.

2. The growth of trade in illegal pesticides is a major concern. A large volume of counterfeit, fake and unauthorised pesticides are reaching farmers, with detrimental consequences for agriculture, the environment, human health and the economy.

3. Available estimates indicate that illegal pesticides account for a larger share of the pesticide market in developing countries, where regulatory and enforcement capacities are generally more limited. However, illegal pesticides are also present in developed countries – with most OECD countries having reported an increasing number of seizures of illegal pesticides in recent years. Importantly, trade in illegal pesticides needs to be addressed as

a transnational issue, as most cases of illegal pesticides involve products crossing the border of different countries before reaching their final destination.

4. The global growth in trade in illegal pesticides has been enabled by the globalisation of pesticide trade since the late 1990's, which has complicated the implementation of regulatory and trade control policies and created greater opportunities and incentives for fraud. Organised crime groups around the world are exploiting gaps in legislation and are using the low effectiveness of traditional detection and control measures to trade poor quality, unregulated products, and extract high profit margins from their sale.

5. New digital technologies, the accessibility, capacity and application of which have boomed in recent years, offer opportunities to tackle this criminal activity. Blockchain, in particular, has been considered a key technology for ensuring full traceability along complex global supply chains, thus reducing opportunities for fraud. In addition to quick and accurate detection of illegal products, blockchain enables secure data exchange between multiple stakeholders, and cross-organisation automation through the execution of smart contracts. A number of blockchain applications for tracking products from source to store have already been successfully piloted and are being implemented, including in the agro-food sector.

6. In addition to blockchain, other digital technologies such as big data analytics and artificial intelligence (AI) can help tackle trade in illegal pesticides by improving the effectiveness of trade control policies. These technologies offer opportunities for enhanced risk-management at borders, automated inspections of containers and cargos, and the monitoring of online trade. The wider adoption of these tools by Customs and other control agencies would significantly reduce the risk of entry and sale of illegal pesticides.

7. While holding great promise, the adoption of new digital technologies also presents a number of challenges. The integration of blockchain tracking solutions, in particular, raises challenges linked to the high investment costs required for information technology (IT) development and infrastructure. This can hinder the adoption of these digital solutions, especially in developing countries where financial resources are more constrained. Other challenges associated with the integration of blockchain include the lack of quality control over the information entered in the system, and the limited interoperability between different blockchain platforms. Getting all the supply chain actors involved and aligned is also likely to be challenging, given the global nature and high number of participants in pesticide supply chains. However, this is essential for ensuring a product's end-to-end traceability and chain of custody during all stages in the supply chain.

8. Finally, blockchain should not be considered a panacea for the trade in illegal pesticides. An effective strategy to tackle this criminal activity would require a combination of policy actions based on new digital technologies (e.g. blockchain, AI, big data analytics, the Internet of things) with other policy interventions beyond those based on these technologies. These include raising public awareness about the risks associated with illegal pesticides and legislative solutions to mitigate their global market penetration (e.g. strengthening of sanctions and closing loopholes in legislation).

1. Introduction

9. Over the past few years, new value chain and data management technologies – e.g., distributed ledger technologies such as blockchain – have been recognised for their potential to improve traceability in increasingly integrated and complex agro-food supply chains. Pilot projects have been proliferating, which could ultimately result in a revolution in the agro-food sector. These new technologies seem particularly relevant in the context of complex value chains with the presence of information asymmetry and misaligned incentives between stakeholders that create opportunities for fraud and illegal practices.

10. Pesticides are an important input for agricultural production. In recent years, however, trade in illegal pesticides has been expanding globally, posing severe threats to agriculture, the environment, and to the health of users and consumers of food (OECD, 2011^[1]). Cracking down on these criminal activities has become more difficult because of the increasing complexity of pesticide global supply chains. Pesticides can cross borders many times before reaching farmers – with product manufacture, assembly and use potentially happening in different countries (Mace and Luda di Cortemiglia, 2016^[2]). Together with the steady increase in cross-border pesticide trade, the complexity of supply chains has created greater opportunities for fraud as it complicates the traceability of products and challenges the effectiveness of traditional trade control policies.

11. This paper explores the opportunities offered by new digital technologies to support the implementation of policy responses to curb trade in illegal pesticides. Two areas of policy action that could benefit from these technologies have been identified: i) the traceability and authentication system for pesticide products and ii) the monitoring and control of pesticide trade, mostly at Customs border posts.

12. Blockchain technology has a strong potential to support the implementation of these two areas of policy action as it enables asset tracking and authentication, and reduces the transaction costs associated with co-ordination and information exchange among multiple stakeholders. In addition to blockchain, other digital technologies such as big data analytics and artificial intelligence (AI) could support strategies to tackle trade in illegal pesticides by improving risk management and fraud identification processes at the border. The wider adoption of these digital tools by supply chain actors and Customs and other control agencies could significantly reduce the risks of entry and sale of illegal pesticides.

13. The rest of the paper is organized as follows. Section 2 provides a definition of “illegal pesticides” and a discussion on their associated environmental and socio-economic risks. It then presents the specific challenges in the pesticide value chain, the main drivers and enablers of trade in illegal pesticides, and the methods used to smuggle these products. Section 3 explores policy responses to the trade in illegal pesticides and the potential contribution of new digital technologies – and in particular blockchain – in facilitating their implementation. Challenges associated with the adoption and use of these technologies are also discussed. Section 4 briefly looks into other policy responses beyond new digital technologies that are essential to efficiently tackle this criminal activity. Concluding remarks are provided in the last section.

2. Trade in illegal pesticides – a growing issue

14. Pesticides are an essential input for agricultural production. They are part of the package of agronomic inputs that supported the large increase in the average yields and global production of major cereal crops since the 1960's (Popp, Petö and Nagy, 2015^[3]).¹ Pesticide use has also enabled higher farm profits by reducing the costs related to labour-intensive tasks such as hand weeding (Cunningham, n.d.^[4]).

15. Handled properly, the use of pesticides can result in growing more food on less land and, in some circumstances, can help to contain the expansion and degradation of agricultural lands and the associated biodiversity loss and greenhouse gas (GHG) emissions from land-use change (Mahmood et al., 2016^[5]). However, due to their toxic nature, pesticides can also represent a significant threat to the environment (National Pesticide Information Center, 2016^[6]). Pesticides applied over land can have detrimental effects on air, soil, and water quality and on non-target plants and animals (Pesticide Action Network UK, 2017^[7]). Furthermore, direct exposure to pesticides and the presence of pesticide residues in food can present risks for human health (Mahmood et al., 2016^[5]).

16. Therefore, a solid regulatory framework often controls the use of pesticides in the agro-food chain to protect farmers, the environment and society as a whole. In most countries, pesticides are authorised for sale only after an independent, science-based risk assessment is conducted by a government agency, to ensure that a correct use of the product will not have adverse effects on the environment or on human health (ECPA, 2019^[8]; Ing. M.H. van Diesen, n.d.^[9]). Whilst legitimate and necessary, these evaluations are costly and often limit the quantity of products available on the market, thereby increasing their price. This creates incentives for the manufacturing and trade of illegal pesticides, to extract above market profits.

2.1. Defining illegal pesticides

17. A pesticide is a mixture of chemicals containing one or more active ingredients and co-formulants that is used to prevent, destroy or control pests – including vectors of human or animal diseases, and unwanted species of plants or animals (OECD, 2018^[10]; OECD, 2001^[11]).² Sub-categories of pesticides include insecticides, fungicides, herbicides, rodenticides, plant growth regulators and others.

18. There is no official, internationally shared, definition of “illegal pesticides” (Mace and Luda di Cortemiglia, 2016^[2]; Food Chain Evaluation Consortium, 2015^[12]). Literature on the issue uses a variety of terms to describe illegal pesticides and provides different classifications of these products (Mace and Luda di Cortemiglia, 2016^[2]). For the purpose of this study, the definition and categorisation in the OECD Best Practice Guidance (BPG) to Identify Illegal Trade of Pesticides will be used (OECD, 2018^[10]).

¹ Since the 1960s, the growing application of fertiliser and pesticides, use of irrigation, and improved crop varieties – also referred to as the “Green revolution” – led to drastic yield improvements in many parts of the world (OECD/FAO, 2019^[72]).

² The active ingredients provide the pesticide action while co-formulants (e.g. emulsifiers, additives, water) facilitate the application of the product.

19. According to this document, an illegal pesticide refers to any product that is not legal in the country where it is “placed on the market” (OECD, 2018_[10]). This includes:

- *Counterfeit and fake pesticides*: illegal copies of a branded, legitimate pesticide. Counterfeit pesticides are characterised by high-quality fake branding and packaging and may therefore be difficult to distinguish from a legal product. In contrast, fake pesticides can be more easily identified due to the poor quality of the product and packaging (OECD, 2018_[10]).
- *Unauthorised pesticides*: pesticide products that are not authorised for use by the regulatory authorities in the country in which they are “being placed on the market” (OECD, 2018_[10]). In most countries, pesticides must be registered by a national government agency, which ensures that they meet the safety standards in force (Ing. M.H. van Diesen, n.d._[9]). Pesticide products that have not been registered are therefore considered illegal. Box 2.1 provides information on the procedure for pesticide authorisation and on data requirements for pesticide risk-assessment.
- *Obsolete pesticides*: pesticide products that are no longer authorised or fit for purpose. Pesticides become obsolete for a number of reasons including product deterioration or degradation, deterioration of the packaging and label, de-registration of the product - due to harmful health or environmental effects – or revised product use recommendations (OECD, 2018_[10]; OECD, 2014_[13]; Mace and Luda di Cortemiglia, 2016_[2]).

Box 2.1. Pesticide registration

Pesticide registration is a scientific, legal, and administrative procedure, which aims to ensure that a pesticide product is effective for its intended purpose and meets safety standards before it can be sold. Pesticide registration also involves the regular review of already registered pesticides to ensure that they meet the latest health and environmental risk-assessment standards. This re-evaluation process can lead to the removal of some products from the market (i.e. pesticide de-registration).

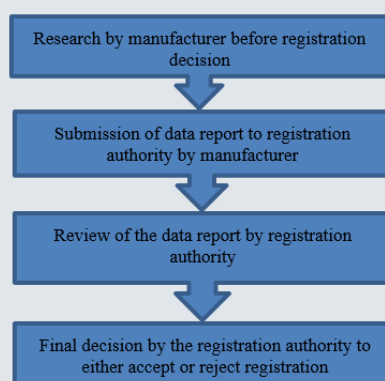
Companies that want to produce a new pesticide or active ingredient must submit a registration dossier to the competent government authority in the country of intended use. A pesticide product will be authorised for sale or export in a specific country only after complete review and assessment of the submitted pesticide dossier and approval by the responsible authority (Figure 2.1).

Pesticide dossiers must usually include:

- Information on the product and its intended use
- Data to identify the product i.e. identity, composition, and physical and chemical properties.
- Data to assess risks to humans and the environment i.e. data on toxicity and on direct and indirect exposure, including residue assessment.
- Data to assess the efficacy of the product when used according to the label instructions.
- Regulatory authorities often require a copy of the label to evaluate and approve the language and ensure the directions for use and safety measures are appropriate to any potential risk.

Pesticide registration is a resource intensive process. Studies required to support a pesticide's registration can cost USD 10 million or more and take several years to complete.

Figure 2.1. The main steps of the pesticide registration procedure



Sources: (FAO/WHO, 2013^[14]; US EPA, n.d.^[15]; Ing. M.H. van Diesen, n.d.^[9]; Mahmood et al., 2016^[5]).

2.2. Environmental and socio-economic impacts of illegal pesticides

2.2.1. Environmental risks associated with illegal pesticide use

20. The impact of pesticide use on the environment is a major public concern. In addition to the poor targeting of pesticide use, pesticides can spillover into the environment at different stages of production, transportation and storage (Pariona, 2017^[16]).³

21. The environmental risks associated with pesticide use mainly include (Kaur and Garg, 2014^[17]; Mahmood et al., 2016^[5]; Aktar, Sengupta and Chowdhury, 2009^[18]):

- Surface and ground water contamination from leaching, runoff or spray drift, and related negative impacts on aquatic forms of life (i.e. aquatic plants and fishes).
- Soil contamination and adverse effects on soil fertility due to the decline of beneficial soil microorganisms and insects (soil bacteria, fungi, earthworms, etc.).
- Air contamination from spray drift or volatilization.
- Adverse effects on non-target organisms. Pesticide use has been associated with the decline of some insects (e.g. pollinators and predators), bird and mammal populations, including endangered species. The application of pesticides can also affect non-target plants and crops and injure nearby trees and shrubs.

22. The probability of the occurrence and the magnitude of these environmental risks mainly depend on: a) the chemical properties of the pesticides, which determine pesticide transport, persistence and water solubility; and b) the application method, timing, and pest management techniques and processes used by the farmer (Pesticide Action Network, 2010^[19]).

23. In view of the environmental risks posed by pesticides, most countries require an environmental-risk assessment of pesticide products before they can be sold and used (see Box 2.1). Government agencies use exposure information and eco-toxicity data to evaluate the potential adverse effects on non-target organisms, air, soil and water. They then consider whether the safety measures proposed by the manufacturer are appropriate to prevent any environmental hazard (WTO and FAO, 2013^[20]).

24. Precisely because illegal pesticides do not go through, or have not been cleared by, this procedure, they represent a significantly higher threat to the environment than legitimate, regulated pesticides. The chemical composition of illegal pesticides is unknown as they have not been tested by a government agency, or have not been approved, and as their labels often misrepresent the product's content. There is therefore no precise knowledge about their impact on crops and on the ecosystem in which they are used (Streloke, 2018^[21]).

25. In terms of minimal harm, illegal pesticides can be inefficient at protecting crops from pests, leading to the spread of diseases on cultivated lands or to higher dosage requirements and/or a more frequent application of these products compared to legitimate pesticides, with associated risks for the environment. (Malkov, Prischepa and Kutonova, 2015^[22]; Federation of Indian Chambers of Commerce and Industry, 2015^[23]). Moreover, illegal pesticides can also destroy and spoil crops or provoke soil infertility, with farmers no longer able to cultivate the contaminated land, as even the smallest change in pesticide

³ Research has shown that over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target pest (Pariona, 2017^[16]).

composition can disproportionately increase toxicity (Malkov, Prischepa and Kutonova, 2015^[22]; UN environment, 2018^[24]). Several cases of major damage to crops after the use of an illegal pesticide have been documented. In 2005, for instance, five farms in Russia and Ukraine reported sugar beet crops losses of up to 75 hectares. These farmers had used a fake pesticide product that they believed to be a legitimate herbicide (ECPA, 2008^[25]).

26. Incorrect pesticide formulations are also likely to have a significantly longer half-life period translating into long-term contamination of soil, ground and surface water, which threaten terrestrial and aquatic biodiversity (Malkov, Prischepa and Kutonova, 2015^[22]).⁴ Obsolete pesticides are also characterised by higher toxicity and environmental persistence, and lower water solubility, and can accumulate in the fatty tissue of living organisms (Pesticide Action Network, 2010^[19]).

27. Finally, the absence or inaccuracy of usage direction on the labels of illegal pesticides can lead to inappropriate application of these products in terms of methods, quantities, and precautions to be taken. For legitimate products, there is an obligation to include an “Environmental Hazard” section on labels, which gives directions to minimize risks to the environment. Labels should also enclose directions regarding the proper storage and disposal of unused pesticides (National Pesticide Information Center, 2016^[6]). Lack of this information can exacerbate the environmental risks associated with illegal pesticides use.

2.2.2. Health, economic and social impacts of illegal pesticides

28. Direct (i.e. pesticide inhalation, ingestion or skin penetration) and indirect (i.e. intake of food produced using pesticides) exposure to pesticides can also present risks for human health.⁵ Human health risk-assessment of pesticides is therefore required before they can be sold and used (Box 1.1). The presence of pesticide residues in food is tightly regulated in some markets – with maximum residue level (MRL) standards ensuring that food produced using pesticides is safe for human health and suitable for consumption (ECPA, 2019^[8]).

29. As with environmental risks, the use of illegal pesticides poses additional health threats to users – mainly farmers – and consumers of food because these products have not been tested, or approved, by a government agency for their impact on human health and may contain highly toxic substances. In addition, their labels often contain incorrect and inadequate safety and personal protection protocols. The fact that the content of illegal pesticides is unknown also increases the time needed to identify the right treatment in case of intoxication (Malkov, Prischepa and Kutonova, 2015^[22]).

30. Moreover, the use of illegal pesticides is associated with adverse economic implications. First, illegal pesticides use can lead to losses of revenues for farmers due to decrease in crop yields or more severe damage to crops (OECD, 2011^[1]). In low-income

⁴ A half-life is the time it takes for a certain amount of a pesticide to be reduced by half. This occurs as it dissipates or breaks down in the environment (National Pesticide Information Center, n.d.^[69]).

⁵ Exposure to pesticides can be associated with both acute and chronic health effects. Acute effects are immediate effects, including headache, skin itching, irritation of the nose and throat, diarrhoea, vomiting, blurred vision, blindness and (very rarely) death. Chronic effects are long-term effects, including neurological health effects, damages to the immune system and multiple body organs, and blood diseases. Exposure to pesticides for prolonged periods of time can also affect reproductive capabilities and has been associated with cancers (Mahmood et al., 2016^[5]).

countries, this can worsen poverty and threaten food security. Farmers who have used illegal pesticides can also face rejection of their products by food companies or customs authorities (when these products are for export), due to excessive residue levels (Mace and Luda di Cortemiglia, 2016^[2]). Farmers might then suffer reputational damage, and subsequent losses of business, which in some cases can affect whole countries where such agricultural and food commodities have been produced, resulting in a total or partial export ban (Malkov, Prischepa and Kutonova, 2015^[22]).

31. The use of illegal pesticides also generates costs for legitimate companies, affecting their reputation and creating trade distortions and unfair competition (OECD, 2011^[1]). Legitimate pesticide producers face losses in sales, as lower price copies of their products reach the market, adversely affecting employment in the pesticide industry as well as decreasing demand for inputs from upstream sectors (Wajsman, Arias Burgos and Davies, 2017^[26]). Legitimate businesses also suffer reputational consequences, including a reduction in consumer confidence in their products because of trademark infringement by counterfeiters (Fishel, 2015^[27]). Trade in illegal pesticides could also ultimately reduce innovation by discouraging legitimate producers from investing in research and development (R&D) to develop new, high quality products (Mace and Luda di Cortemiglia, 2016^[2]).

32. Reduced activity in the legitimate pesticide industry also has an impact on government revenue. As for any illegal activity, actors engaged in the manufacture and trade of illegal pesticides do not declare their revenue to authorities and therefore do not pay taxes on the latter (Wajsman, Arias Burgos and Davies, 2017^[26]). These losses in government tax revenue further reduce regulatory capacity and enforcement resources (Mace and Luda di Cortemiglia, 2016^[2]).

33. The European Union Intellectual Property Office (EUIPO) estimates that, when both direct and indirect effects are considered, counterfeiting in the pesticide sector causes approximately EUR 2.8 billion of lost sales to the EU economy, which in turns leads to employment losses of about 11,700 jobs and a loss of EUR 238 million in government revenue (Wajsman, Arias Burgos and Davies, 2017^[26]).

34. Trade in illegal pesticides can also have detrimental effects on the functioning of societies and public authorities, as it is often associated with corruption and sometimes with other areas of crime (OECD, 2011^[1]). Organised crime groups (OCGs) and networks engaged in the production and distribution of illegal pesticides often rely on corrupt custom officers, law enforcement officials and staff in charge of pesticide procurement (Mace and Luda di Cortemiglia, 2016^[2]). Attractive profit margins contribute to conspiracy and corruption at every stage of the pesticide life cycle, which complicates the control and prosecution of criminal activity (Malkov, Prischepa and Kutonova, 2015^[22]). Finally, trade in illegal pesticides undermines national registration and risk reduction schemes, weakening public confidence in regulatory and compliance policies put in place by governments (OECD, 2011^[1]).

2.3. Estimating the size of trade in illegal pesticides

35. Trade in illegal pesticides refers to any form of trade in a pesticide that violates the law of importing countries, including counterfeit, fake and un-registered pesticides (see definition) (OECD, 2019^[28]). It is difficult to find detailed data on the magnitude (i.e. trade volume and value) and growth of trade in illegal pesticides because of its unlawful nature (ECPA, 2008^[25]). Available estimates are based on scattered data (e.g., collected during

control and investigation) and vary widely, as is the case for all sectors affected by counterfeiting and illegal activities (ECPA, 2008^[25]; OECD, 2011^[11]).

36. Another challenge arises from the fact that the discovery of illegal pesticides is not always declared, as authorities may prefer to deal discreetly and directly with the concerned parties. One explanation for this approach is the desire to avoid reputational consequences and legal repercussions associated with the distribution and use of illegal pesticides.

37. By one estimate, the share of illegal pesticides on global markets increased from 5%-7% to 10% between 2007 and 2011 (Guyer and Davreux, 2012^[29]). Since then, estimates have ranged from 10% to 15%, up to 25% according to the Organization for Security and Co-operation in Europe (OSCE) (Europol, 2011^[30]; Malkov, Prischepa and Kutonova, 2015^[22]; Food Chain Evaluation Consortium, 2015^[12]; UN environment, 2018^[24]).

38. With the global pesticide market valued at over USD 60 billion, global revenues associated with the trade of illegal pesticides are estimated at USD 6-10 billion, which is comparable to the annual global market of illegal transportation of waste (USD 10-12 billion) and endangered species (USD 7-23 billion). This makes trade in illegal pesticides one of the top ten most lucrative organized crime businesses in the world (Malkov, Prischepa and Kutonova, 2015^[22]; Mace and Luda di Cortemiglia, 2016^[2]).

39. The scope and scale of illegal pesticide presence varies from one market to another depending on regional and individual country specificities (ECPA, 2008^[25]). National farmers and industry associations in Africa estimate that 15% to 20% of the pesticide market is illegal, with particular hotspots where small scale domestic preparations and imports of illegal agricultural chemicals and counterfeit pesticides may account for up to 80% of the pesticide market (Guyer and Davreux, 2012^[29]). In Asia, notably in China and India, illegal pesticides are a major issue. In those two countries, illegal pesticides are estimated to account for approximately 30% of the pesticide market; in India, 30% of this market is estimated to be the result of illegal imports (Mace and Luda di Cortemiglia, 2016^[2]; Federation of Indian Chambers of Commerce and Industry, 2015^[23]).⁶ In Brazil – the leading agricultural exporter in South America – illegal trade in pesticides is considered to account for a significant and growing share of the national pesticide trade; it was estimated at around 9% in 2009 (OECD, 2011^[11]). Illegal pesticides are also a major concern in Argentina, Paraguay and Uruguay (Mace and Luda di Cortemiglia, 2016^[2]).

40. Farmers in developing countries are particularly vulnerable to illegal pesticides due to relatively more limited regulatory and enforcement capacities and more limited public awareness of the issue (Mace and Luda di Cortemiglia, 2016^[2]). The scale and growth of illegal pesticides in developing countries is particularly worrying, as significant agricultural productivity increases are needed in these countries to support food security and farmer livelihoods (Federation of Indian Chambers of Commerce and Industry, 2015^[23]).

41. While illegal pesticides seem to be a bigger issue in developing countries, it is also a large and growing concern for developed countries and, in particular, for European countries with large agricultural sectors. Illegal pesticides have been estimated at over 10%

⁶ In these two countries, the increase in the illegal pesticide market has been facilitated by the rapid growth of chemical-manufacturing capabilities - including agricultural chemicals - over the last decade (RSK ADAS Ltd, 2015^[37]). This suggests that illegal actors are able to source and produce illegal pesticides in countries that produce and distribute the legitimate chemical precursors (Food Chain Evaluation Consortium, 2015^[12]).

of the European Union (EU) pesticide market (Mace and Luda di Cortemiglia, 2016^[2]; Food Chain Evaluation Consortium, 2015^[12]). More recently, EUIPO estimated that counterfeit pesticides accounted for 13.8% of pesticide sales in the EU, resulting in the loss of about EUR 1.3 billion in sales for the legitimate pesticide industry (Wajsman, Arias Burgos and Davies, 2017^[26]).

42. The main source of illegal pesticides in Europe is illegal parallel imports, where legitimate parallel imports of products are substituted with illegal copies.⁷ Illegal parallel traders import non-original chemicals from third countries, then place them in new containers and sell them to farmers as if they were originals that have been purchased in another EU country to permit legitimate price competition. This is possible due to the lack of requirements to link parallel imported products to their batch of origin – i.e., their reference batch number – at the time of sale (Section 4) (Food Chain Evaluation Consortium, 2015^[12]; European Crop Protection Association, 2019^[31]).⁸

43. In view of the proliferation of illegal pesticides in Europe, Europol started in 2015, the Silver Axe Operation, an annual enforcement operation targeting trade in illegal pesticides. Data on seizures from this operation give some further indication of the magnitude and growth of this criminal activity in Europe (Box 2.2).

Box 2.2. The Silver Axe Operation

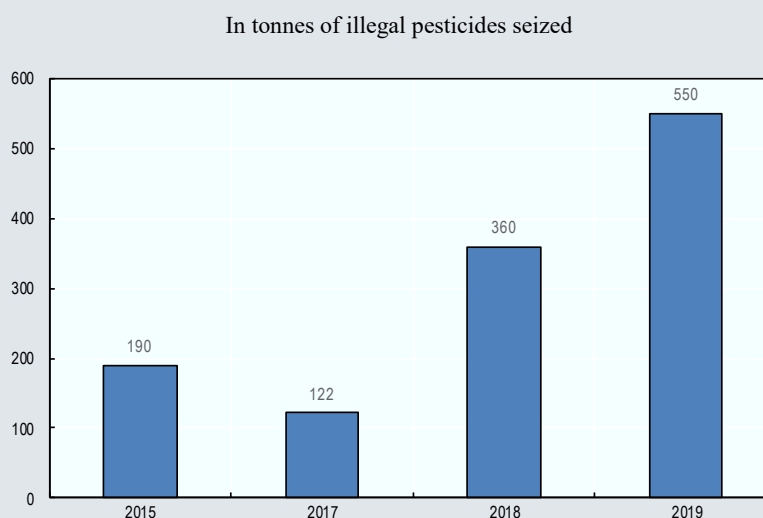
The Silver Axe operation is an annual enforcement operation that originally focused on the sale and import of illegal pesticides in Europe, but which currently operates beyond European borders. It is coordinated by Europol, with support from the European Anti-Fraud Office (OLAF). At its launch in 2015, the Silver Axe operation involved seven EU countries. Since then, the number of participating countries has been increasing, up to twenty-nine in 2019, including two non-EU countries (Ukraine and Switzerland).

This international operation involves close collaboration between law enforcement agencies in participating countries to exchange and analyse data; and liaison with European and international plant protection bodies (e.g. CropLife, European Crop Protection Agency), as well as with private pesticide companies.

In the course of the four editions of the Silver Axe operation, police and law enforcement officers have carried out checks at major seaports, airports, and land borders as well as at pesticide production and repackaging facilities in participating countries. These checks are usually carried out over the course of ten to twenty days. They have resulted in the seizure of 1 222 tonnes of illegal pesticides across Europe (Figure 2.1). In 2019, seizure of illegal pesticides reached a record high at 550 tonnes, roughly enough to spray an area the size of Estonia (i.e. 49 000 km²). The 4th edition of the Silver Axe operation also led to the arrest of three individuals.

⁷ Parallel imports can be defined as the ability to import a product under IPR protection, without the consent from the IPR holder, from another market where it is also produced but at a lower price. This process generally involves some repackaging in order to meet markets access requirements (e.g. translation of the safety instructions). In the EU, parallel imports of pesticide products is legal. However, it has been increasingly misused to move illegal pesticides around the EU and bring them to the market.

⁸ According to European industry body, source countries for imported illegal pesticides include China, India, Malaysia, Indonesia, Turkey and Ukraine (Food Chain Evaluation Consortium, 2015^[12]).

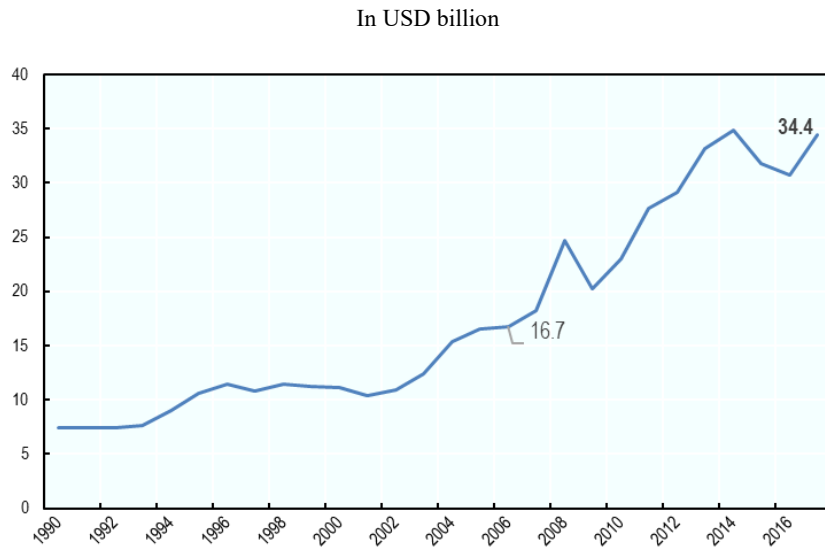
Figure 2.2. Seizures of illegal pesticides as part of the Silver Axe operation

Source: (Europol, 2017^[32]; Europol, 2015^[33]; Europol, 2019^[34]; Europol, 2018^[35]).

2.4. Key drivers and enablers of trade in illegal pesticides

44. Several factors have contributed to an increase in trade in pesticide products. The global growth in demand for agricultural production – due to rising world population and increasing per capita wealth – has led to an increase in demand for pesticides. As a result, cross-border trade in legal pesticides has been dramatically increasing, especially in the last decade (Figure 2.3). These growing trade flows have put strong pressure on border authorities who often lack the resources to ensure proper oversight, leading to a corresponding rise in illegal pesticide trade (Mace and Luda di Cortemiglia, 2016^[2]). While not all illegal pesticides are the result of trade (as noted above, some are the result of “home grown” providers), this paper focuses on the role of such trade in the proliferation of illegal pesticides.

45. Illegal pesticides are attractive to farmers because they are less expensive than legitimate products. Their price can be as much as 40% lower than the price of legitimate, branded pesticides (Federation of Indian Chambers of Commerce and Industry, 2015^[23]). Demand for illegal pesticides can also be explained by end users’ lack of awareness of the risks associated with their use and on how to identify them (Federation of Indian Chambers of Commerce and Industry, 2015^[23]; UN environment, 2018^[24]; Mace and Luda di Cortemiglia, 2016^[2]). It can be extremely difficult for farmers to differentiate between authentic and illegal pesticides as counterfeiters use elaborate techniques to make their products appear genuine (see next section). Finally, demand exists for unauthorised pesticides, including broad-spectrum pesticides that are being banned in many markets across the world (Ing. M.H. van Diesen, n.d.^[9]).

Figure 2.3. Global pesticide export value, 1990-2017

Source: (FAOSTAT, 2019^[36]).

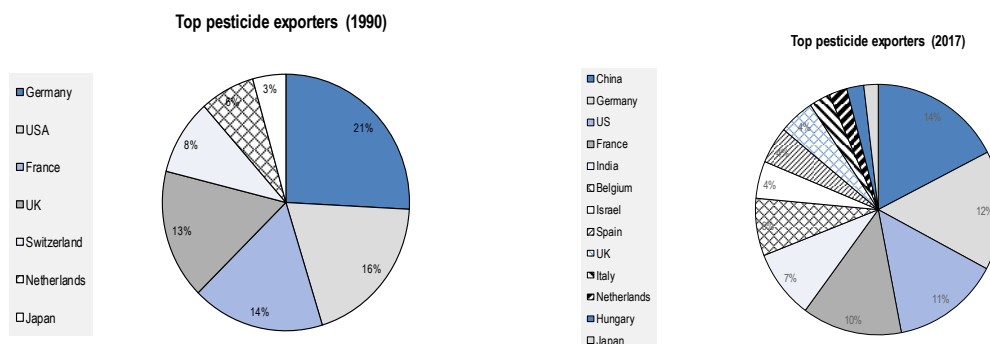
46. In addition, the shape of pesticide supply-chains is changing and global supply chains are becoming increasingly complex, involving up to twenty-five different entities – ranging from manufacturers to shippers and distributors – with production, shipment, assembly and distribution points scattered over multiple geographical locations. The number of parties, transfers and stops involved in pesticide trade has complicated regulatory and control efforts, as well as the identification of illegal products (Mace and Luda di Cortemiglia, 2016^[2]).

47. Until the 1990s, pesticide manufacturing was concentrated in a few countries, with Germany, the United States (US), France and the United Kingdom (UK) accounting for the majority of global pesticide exports. Since then, a number of new legitimate pesticide exporters – including China and India - have emerged leading to a diversification of suppliers in the global marketplace (Figure 2.4).

48. Inspection and tracking systems have not kept up with this growing complexity. As a result, a large share of illegal pesticides has been moving through legitimate supply chains without detection or seizure. This low risk of detection – together with the minor legal or financial consequences associated with the seizure of illegal pesticides in most jurisdictions – have increased opportunities and incentives for fraud, enabling this criminal activity to expand globally.

Figure 2.4. Top pesticides exporters in 1990 and 2017

In share of global pesticide export value



Note: Taken together, countries display in the graphs account for 80% of total pesticides export value in 1990 and 2017, respectively.

Source: (FAOSTAT, 2019^[36]).

49. Another key driver of trade in illegal pesticides is the high profit margins associated with this criminal activity. According to the Federation of Indian Chambers of Commerce and Industry (FICCI), the margins on non-genuine, illegal pesticides can be as much as 25-30%, compared to 3-5% for legitimate products (Federation of Indian Chambers of Commerce and Industry, 2015^[23]). Several factors contribute to these high profit margins. First, through the production of illegal pesticides, criminal actors avoid all the costs associated with the development and marketing of a new brand name product (e.g., R&D costs) (Mace and Luda di Cortemiglia, 2016^[2]). Furthermore, illegal producers do not face the high regulation costs associated with pesticide authorisation (see Box 2.1). Pesticide registration is a long and costly process that can act as a barrier to entry for new businesses, making illegal activities attractive for criminal actors (Federation of Indian Chambers of Commerce and Industry, 2015^[23]).

50. In addition, illegal producers might incur considerably lower production costs due to the poor composition of their products. Illegal pesticides are usually less concentrated than legitimate products, contain cheaper or smaller quantities of active ingredients, and can be made of diluted and obsolete pesticide stocks or even water or talc (RSK ADAS Ltd, 2015^[37]; ECPA, 2008^[25]).

2.5. Methods used to smuggle illegal pesticides

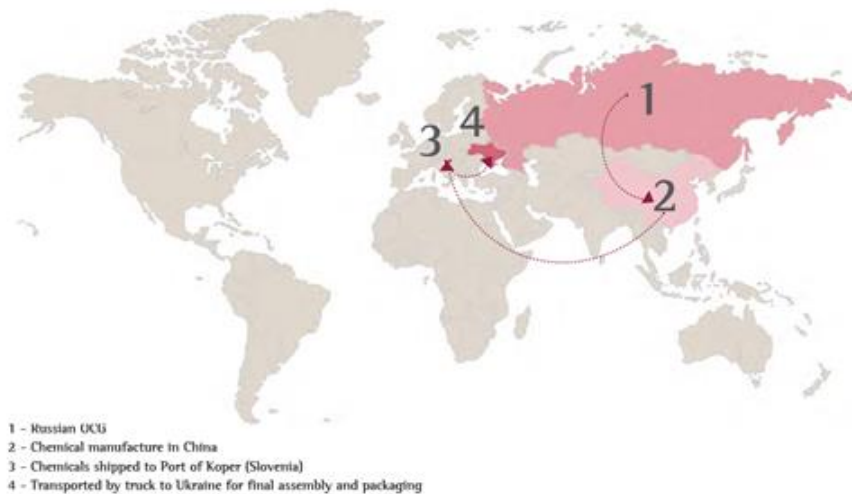
51. Actors engaged in trade in illegal pesticides range from loosely organised groups – sometimes just a few individuals – to highly organised criminal networks. There is growing evidence that sophisticated counterfeits are produced and distributed by large organised criminal groups (OCGs), who conduct the majority of illegal trans-border shipments (Mace and Luda di Cortemiglia, 2016^[2]; ECPA, 2008^[25]).

52. Misrepresentation of product content is one of the main methods used by illegal actors to avoid risk-profiling measures at custom borders, as well as regulatory and customer scrutiny. Illegal actors relabel and repack pesticides or refill legitimate pesticide containers to make their products appear genuine (Europol/OHIM, 2015^[38]). Forged transport documents are also used to conceal the content of containers and packages (Europol/OHIM, 2012^[39]). As importing unbranded items is not illegal, criminal actors

might further avoid border detection by sending products and labels separately – possibly through different ports – and printing counterfeit trademark labels on their products just before sale (Europol/OHIM, 2015_[38]; Mace and Luda di Cortemiglia, 2016_[2]). Criminal networks also import active ingredients to be formulated, packed and labelled near or within the country of destination, which prevents detection at the border and complicates the traceability of finished products (Mace and Luda di Cortemiglia, 2016_[2]; Food Chain Evaluation Consortium, 2015_[12]; OECD, 2011_[1]).⁹

53. Criminal groups also rely on various sophisticated techniques to disguise the origin and provenance of illegal pesticides and hinder product traceability along the supply chain (Mace and Luda di Cortemiglia, 2016_[2]). This includes the use of deliberately complex and long transit routes, crossing borders of multiple countries and relying on several transportation modes (e.g. sea, air, overland transport) (Ing. M.H. van Diesen, n.d._[9]; Europol/OHIM, 2012_[39]). Forged transport documents are also used to conceal the point of origin. Moreover, criminal actors can avoid detection by using distribution warehouses and self-storage facilities in transit countries for the assembly and distribution of illegal pesticides. They can also fail to declare a product for customs control at checkpoints or reroute a shipment (Mace and Luda di Cortemiglia, 2016_[2]). Figure 2.5 illustrates the complexity and transnational character of trade in illegal pesticides.

Figure 2.5. Real world example of trade in illegal pesticides



Note: A Russian OCG who acts as a broker, orders chemicals used in the production of pesticides from China. The chemicals are transported by container shipments to a port in Slovenia and then by truck into Ukraine, where the pesticides are manufactured, labelled and packaged for further distribution across the EU.

Source: (Europol/OHIM, 2015_[38]).

54. Finally, illegal actors also directly sell their products to farmers via the Internet, which has become a major enabler for the distribution and sale of counterfeit and illegal pesticides (Mace and Luda di Cortemiglia, 2016_[2]). For instance, illegal pesticides imported in the US as a result of online sales on Amazon are estimated to be quite large in number, with nearly 4 000 violations of the Federal Insecticide, Fungicide, and Rodenticide

⁹ It is also more lucrative to only transport active ingredients and add other product constituents near the point of sale as active ingredients might only makes up for about 1-5% of the total product.

Act (FIFRA) over the last five years (Clarridge and V.Mapes, 2018_[40]).^{10,11} Moreover, online sales of pesticides usually involve small parcels that do not always follow the same pathway as large shipments and often cross borders via postal or express services, reducing the effectiveness of traditional detection and seizure strategies (Jouanjean, 2019_[41]) (Malkov, Prischepa and Kutonova, 2015_[22]).¹²

55. Thus, trade in illegal pesticides has been underpinned by an increasingly sophisticated fraud system that traditional traceability and risk management systems have struggled to control. Consequently, government agencies have to reconsider their fraud detection and enforcement tools and develop a range of policy responses to these new challenges, the implementation of which can benefit from the use of digital technologies such as blockchain.

¹⁰ FIFRA is the federal statute that governs the registration, distribution, sale, and use of pesticides in the United States.

¹¹ Amazon has been ordered by the US Environmental Protection Agency to pay fines of USD 1.2 million for allowing third-parties to sell imported unregistered pesticides in the US (Clarridge and V.Mapes, 2018_[40]).

¹² According to the OSCE, 70% of counterfeit pesticides come in small packages for private agricultural producers and small farmers (Malkov, Prischepa and Kutonova, 2015_[22]).

3. Policy responses that can be supported by new digital technologies

56. Based on the discussion in Section 2 above, two areas of policy action that could benefit from the support of new digital technologies have been identified: i) the traceability and authentication system for pesticide products; and ii) the monitoring and control of pesticide trade, mainly at custom borders.

57. This section first provides definitions of the new digital technologies that could be used to counter trade in illegal pesticides. Next, it explores their potential in facilitating the implementation of specific policy responses – with a focus on enhancing the security and integrity of pesticide authentication and traceability system, and improving the effectiveness of trade control policies for pesticide products. Risks and challenges associated with the adoption and use of these technologies are also discussed.

3.1. New digital technologies – definitions and concepts

58. *Blockchain* technology is a form of distributed ledger technology (DLT) that acts as an open and trusted record of transactions from one party to another (or multiple parties) and that is not stored by a central authority (Box 3.1) (Berryhill, Bourgerie and Hanson, 2018^[42]). The core characteristics of blockchain are (Gaspar, 2019^[43]):

- A decentralised system not reliant on trust: no single individual or entity is trusted with record keeping. Instead, all actors within the blockchain can validate the change of state of the ledger. This eliminates the possibility of fraud by one single authority.
- Data provenance: the time and origin of every entry into the blockchain is easily identifiable and traceable.
- Immutability: it is (almost) impossible to change or delete records once they have been entered in the blockchain.

Box 3.1. Blockchain, key concepts and definitions

Distributed Ledger Technology (DLT): A technology upon which records of transactions are spread across multiple sites, countries or institutions, and is typically public. Transaction records are stored one after the other in a continuous ledger, but they can only be added when participants confirm the feasibility and validity of the transaction.

Node: A node is simply a user or computer on a blockchain platform that stores the ledger.

Cryptography: Cryptography is the act of creating codes that allows data to be kept secret. Cryptography converts this data into a format that can only be read/decoded by authorised users. Thus, the data can be transmitted without fear of it being decrypted and compromised by unauthorised actors. Authorised actors may decrypt the data using a “key”, which is essentially a corresponding private code that only an authorised user should know.

Tokenisation: the term tokenisation describes the process of transferring rights to a real world asset into a digital representation – or token – on the blockchain. Being in possession of that digital token then gives one the right to that asset and the ability to trade and track it digitally. There are three main types of tokens:

- **Payment token:** commonly known as a cryptocurrency, a payment token can be a store of value and a unit of measurement, e.g. Bitcoin.
- **Utility token:** a token that represents a right to a good or service, similar to a gift card, e.g. StorjCoin.
- **Security token:** a token that provides equity or equity like investment in a company. The holder of the token has rights to the company’s future profits, e.g. tZERO.

Sources: (Berryhill, Bourgerie and Hanson, 2018^[42]; OECD, n.d.^[44])

59. There is not one but many different blockchain technologies, all presenting different features and modes of governance. The most appropriate type of blockchain will depend on which problem it is intending to solve (Box 3.2).

60. *Big data analytics* allows for the processing and interpretation of large volumes of structured and unstructured data in different formats to infer relationships, establish dependencies, and perform predictions of outcomes and behaviours. Such analysis can help inform real-time decision-making by combining a wide range of information from different sources (Jouanjean, 2019^[41]) (Okazaki, 2017^[45]).

61. *Artificial intelligence (AI)* is defined as the ability of machines and systems to acquire and apply knowledge and to carry out intelligent behaviour. AI or cognitive-based technologies help computers interact, reason, and learn like human beings to perform a broad variety of cognitive tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. Intelligent systems usually rely on a combination of big data analytics, cloud computing, machine-to-machine communication and connected devices – internet of things (IoT) – to learn and operate (Jouanjean, 2019^[41]).

Box 3.2. The different type of blockchain technologies

Two of the most important features of blockchain technology are the “openness” of the platform (i.e. public or private) and the level of permissions required to add information to the blockchain (i.e. permissioned or permissionless) (Table 3.1). In the context of public permissionless blockchain, such as Bitcoin for instance, anyone can read and add data to the ledger.

For supply chain traceability and management, a public permissioned blockchain seems to be the most appropriate type. Public permissioned ledgers can greatly enhance accountability, as transactions can be transparent to everyone (e.g. consumers), while only authorised users are able to actually record new transactions (Berryhill, Bourgerly and Hanson, 2018^[42]). For our use case, regulatory authorities or a blockchain provider could be in charge of issuing permission to write on the ledger to legitimate actors along the pesticide supply chain. These actors will be responsible for updating the blockchain and maintaining a decentralized system.

Table 3.1. Main types of blockchain segmented by permission model

			Read	Write	Commit	Example
Blockchain types	OPEN	Public permissionless	Open to anyone	Anyone	Anyone	Bitcoin, Ethereum
		Public permissioned	Open to anyone	Authorised participants	All subset of authorised participants	Supply chain ledger for retail brands viewable by public
	CLOSED	Consortium	Restricted to an authorised set of participants	Authorised participants	All or subset of authorised participants	Multiple banks operating shared ledger
		Private permissioned (“enterprises”)	Fully private or restricted to limited set of authorised nodes	Network operator only	Network operator only	External bank ledger shared between parent company and subsidiaries

Source: (OECD, n.d.^[44]).

3.2. Enhancing traceability and authentication of pesticide products along the supply chain

3.2.1. What are the policy responses?

62. As discussed in Section 2, the authentication and traceability of pesticides have been severely challenged by illegal practices – e.g., the use of forged labels and transport documents – in the context of increasing complexity of supply chains.

63. Currently, the authentication and traceability of pesticides mainly relies on the labelling, both on the products and the containers, as well as the shipping documents – e.g., bills of lading and export documents – that should include information on product content, lot or batch number, origin and destination, and means and routes of transportation.¹³ However, transport documents are still largely paper-based and transmitted from one party to another along the supply chain, creating significant opportunities for fraud, errors and

¹³ In principle, the batch number should be available on all pesticide products, enabling traceability back to their original batch and identification of their origin.

inefficiencies (Jouanjean, 2019^[41]). Labels are not always explicit and can also be easily tampered with. Moreover, countries have different standards regarding the content and format of labels, which makes it very challenging for border and regulatory authorities to determine whether or not a label is authentic (Gaspar, 2019^[43]).¹⁴

64. Therefore, a more robust system is required to trace ready-to-use pesticides and upstream agricultural chemicals. End-to-end supply chain transparency would enable closer monitoring of the supply chain, help detect points of failure and reduce the response time in case of incident (Singh et al., 2017^[46]; Mace and Luda di Cortemiglia, 2016^[2]). Moreover, by capturing all stakeholders involved in the supply chain and their respective roles and responsibilities, full traceability can create accountability (Singh et al., 2017^[46]). Finally, improved pesticide traceability will reinforce consumer trust in products, as they would be able to more easily verify their provenance and authenticity prior to use.

3.2.2. How can new digital technologies help?

65. The core characteristics of blockchain enable secure peer-to-peer transactions – i.e., exchange of value and data – between parties with no prior transacting relationship. Until now, blockchain technology has been mainly used in the financial sector for monetary transactions, with Bitcoin being the most famous of these applications. However, blockchain can also benefit other sectors and other, non-monetary, purposes. In particular, blockchain has been considered an efficient tool for supply chain management, with potential applications for supply chain due diligence and tracking from origin to distribution for food products, medicines, and natural resources (Berryhill, Bourgerie and Hanson, 2018^[42]; OECD, 2019^[47]).

66. Blockchain enables asset tracking and authentication because of its ability to create unique identities for individual items (Radocchia, 2018^[48]). A physical asset can be tracked on the blockchain by associating it to a unique digital asset. This process is called “tokenisation” (Box 3.1). The token (digital asset) can be, for instance, a digital representation of a good, a container or a shipment. Each change of state of this token (e.g., a change of ownership or arrival at a port of entry) is registered and time stamped on the blockchain (Gaspar, 2019^[43]). The representation of a supply chain through a blockchain thus provides a digital database that permanently records, tracks, monitors and transacts physical and digital assets (Tripoli and Schmidhuber, 2018^[49]).

67. In case of product tracking, an immutable link has to be established between the product and its digital life on the blockchain for the transactions to be fully tamper-proof. This can be ensured through the use of innovative packaging technologies such as quick response (QR) codes, the more advanced radio frequency identification (RFID) chips or crypto-anchors (Tripoli and Schmidhuber, 2018^[49]).¹⁵ Once this immutable product-process link has been established, transactional data are recorded and verified by the blockchain – in a transparent and immutable fashion – as the product moves from the manufacturer to final consumers. Each transaction that is processed on the blockchain can carry transaction details and specific attributes for the product which can be added by

¹⁴ The United Nations *Globally Harmonized System of Classification and Labelling of Chemicals* (GHS) provides guidelines for hazard communication and labelling standards for chemical products - including pesticides. This can be used as a baseline for international harmonisation of pesticide labelling (United Nation, 2011^[73]).

¹⁵ Crypto-anchors are tamper-proof digital fingerprints that are embedded into products, or parts of products, and linked to the blockchain to prove product authenticity.

supply chain actors (Tripoli and Schmidhuber, 2018^[49]). Everyone with access to the blockchain can therefore examine the product’s movements along every step of the supply chain and access real time information about the product being shipped (Jouanjean, 2019^[41]).

68. Figure 3.1 gives an example of the type of digital information that could be entered in the blockchain by the stakeholders at each stage of the pesticide supply chain. In order to have full product traceability, the manufacturer would first register each of their products on the blockchain and upload information on the name, chemical composition, batch number, and on the type of packaging used. The blockchain will then be updated each time the product changes hands. Other types of information that would be recorded along the supply chain include the name and address of each participant, the dates of shipment and import, and the quantities of pesticide shipped and imported.

Figure 3.1. Information on the pesticide supply chain entered in the blockchain

MANUFACTURER	FORMULATOR	EXPORTER	TRANSPORTER	IMPORTER	RETAILER	CONSUMER
<ul style="list-style-type: none"> - Pesticide name and composition - Date of manufacture - Batch number - Type of packaging - Name and address of manufacturer and purchaser - Date of sale - Destination country 	<ul style="list-style-type: none"> - Name of base material used - Name and address of provider - Product composition/recipe - Destination country 	<ul style="list-style-type: none"> - Pesticide name - Name and address of exporter - Name, address and country of consignee - Date of shipment - Quantity shipped - Registration dossier - Export certificate 	<ul style="list-style-type: none"> - Invoices - Material data safety sheets - Export certificates - Electronic export information - Packaging lists 	<ul style="list-style-type: none"> - Pesticide name - Name and address of importer - Date of import - Name, address and country of consignor - Date of shipment by consignor - Quantity imported 	<ul style="list-style-type: none"> - Pesticide name - Name and address of supplier and purchaser - Date of purchase and sale - Batch numbers - Pack size - Quantity/volume purchased and sold 	<ul style="list-style-type: none"> Gets full information on the product (e.g. composition, origin, chain of custody)

Note: example and non-exhaustive set of information.

Source: Author based on OECD BPG to Identify Illegal Trade of Pesticides (OECD, 2019^[28]).

69. Consequently, blockchain-based systems can allow for the rapid identification and reporting of suspicious activities within the supply chain and for the legal accountability of fraudulent behaviour (Radocchia, 2018^[48]; Tripoli and Schmidhuber, 2018^[49]). For instance, if a product or a container is diverted (e.g., sold to an unauthorized dealer), the disappearance of these items from the supply chain can be quickly detected – due to the observable inconsistencies between quantities shipped and imported – and traced back to the last party that had custody of the products. Counterfeit and fake goods will also be easier to identify because they will not be assigned a registered blockchain identity (Radocchia, 2018^[48]). The monitoring of the pesticide supply chain using blockchain would therefore make it much more difficult for illegal actors to sell their products, reducing the attractiveness and the “risk-profit” margin associated with this criminal activity (Radocchia, 2018^[50]). Moreover, consumers would be able to easily verify the product’s authenticity and access key information about the product they buy – e.g. by scanning a QR code on product packaging – enabling more informed purchasing decisions (World Economic Forum, 2018^[51]).

70. A number of blockchain pilot applications have already been tested and are being implemented in the agro-food sector. For instance, IBM has developed a blockchain tracking system to promote safer and smarter food supply chains. IBM Food Trust connects participants across the food supply chain (i.e. producers, suppliers, manufacturers, retailers and ultimately consumers), through a permanent and shared record of transaction and food system data, significantly reducing opportunities for fraud. Walmart and Carrefour, have already adopted this technology to provide consumers with more trust in their products and

differentiate their brands from competitors (IBM, n.d._[52]). A growing number of start-ups are also developing blockchain-based solutions to trace food products from source to store (e.g. Ambrosus), provide agricultural supply chain actors with better data on crop production (e.g. Ripe) or curb illegal fishing and fake certifications (e.g. Provenance) (Tripoli and Schmidhuber, 2018_[49]).

71. Other blockchain applications currently in development focus on improving the traceability of agricultural inputs. For instance, the SICPA blockchain-based system aims to enhance the traceability of seeds in Brazil and ensure regulatory compliance.¹⁶ SICPA is also working with the United Nations Interregional Crime and Justice Research Institute (UNICRI) to develop blockchain-based systems to address supply chain security risks related to illegal pesticides (UNICRI, n.d._[53]). Finally, the OECD Seed Scheme is currently exploring how blockchain technology can improve the security of the existing paper-based seed lot identification and traceability system in place in OECD countries (Gaspar, 2019_[43]).

3.2.3. *Challenges to the implementation of new digital technologies*

72. As with many emerging technologies, there are a number of risks to manage and challenges to overcome in order to harness the full potential of blockchain (World Economic Forum, 2018_[51]).

73. First, building and deploying blockchain solutions requires significant technical and financial resources compared to traditional solutions such as centralised databases (Leon, 2018_[54]). This includes the high investment costs required for information technology (IT) development and infrastructure, which have been estimated at USD 660 000 for private blockchain solutions (EY, 2019_[55]). In the case of a blockchain application for supply chain traceability, significant investment costs are also required to link physical products to their digital life on the blockchain (OECD, n.d._[44]). Legitimate manufacturers would have to invest in new packaging technologies to make sure that this link cannot be replicated (Tripoli and Schmidhuber, 2018_[49]). These large upfront costs are hampering widespread deployment of blockchain technology (Berryhill, Bourgerie and Hanson, 2018_[42]). The adoption of blockchain in developing countries – where illegal pesticides is a major issue – seems particularly challenging, given the more limited financial resources and the often lower quality of the IT infrastructure.

74. The lack of quality control over the information initially entered into the blockchain is another challenge for supply chain applications. While blockchain provides data immutability, there is no mechanism to guarantee the truthfulness of the information that is uploaded at the origin, which can significantly reduce the value of blockchain to supply chain actors and end-users. To eliminate opportunities for fraud, adequate regulations to control data processes and the establishment of data standards are required (Jouanjean, 2019_[41]; Berryhill, Bourgerie and Hanson, 2018_[42]). The combination of blockchain with other technologies such as the Internet of Things (IoT) (e.g. sensors) can also help reduce concerns over data quality by minimizing human input into the shared ledger (OECD, 2019_[47]).

75. Finally, the current absence of an adequate legal and regulatory framework for blockchain applications is also hindering widespread deployment of the technology. For supply chain applications, one particular concern relates to the regulatory implications

¹⁶ SICPA is a global provider of secured authentication, identification and traceability solutions.

regarding data security and privacy among participants (World Economic Forum, 2018^[51]). Transactions may include some types of confidential information, such as personal data or data related to business processes, that participants do not wish to become public knowledge or that data privacy regulation may prevent from being accessible. Careful consideration should be given to the type of data that should be protected, while still providing incentives to supply chain actors to share key data that are essential to guarantee transparency (Tripoli and Schmidhuber, 2018^[49]).

3.3. Improving monitoring and control of trade in pesticides

3.3.1. What are the policy responses?

76. The globalisation and growth of pesticide trade has complicated the implementation and reduced the effectiveness of traditional trade control policies. As a result, a large share of illegal pesticides has been moving through legitimate supply chains without detection or seizure (Section 2). The effectiveness of trade control policies for pesticide products is also constrained by lack of awareness (or interest) of responsible authorities, poor inter-agency cooperation at national and international levels, and the limited financial resources for qualified staff, equipment and laboratory testing at customs borders (Food Chain Evaluation Consortium, 2015^[12]; Mace and Luda di Cortemiglia, 2016^[2]).

77. Customs agencies play a crucial role in detecting and inspecting suspicious shipments of pesticides. In particular, customs risk analysis carried out at the border should be at the forefront of any anti-smuggling strategy.¹⁷ The wider adoption of customs analysis and risk management systems – as opposed to random checks – would enable higher detection rates of illegal shipments. Pesticide imports are mainly controlled through the inspection of supporting documentation, visual control of packaging and labelling, and, in case of suspicion of illegality, sampling and laboratory analysis of the products (Malkov, Prischepa and Kutonova, 2015^[22]).

78. Enhanced cooperation and information exchange between the multiple agencies responsible for the control of pesticide trade (e.g., customs, regulatory authorities) would also enable more effective detection of illegal pesticides. Greater efforts could be made by national agencies to set up tools and mechanisms to facilitate the exchange of operational and intelligence data among them, as well as with their counterparts in other countries, and in particular with agencies in countries that are suspected to be a source of illegal pesticides (Ing. M.H. van Diesen, n.d.^[9]; Malkov, Prischepa and Kutonova, 2015^[22]).¹⁸ At the OECD level, countries have set up a Rapid Alert System, which is used by inspectors to exchange information about suspicious or rejected shipments of pesticides (OECD, 2019^[28]).¹⁹

¹⁷ Risk analysis is used by customs agencies to identify and quantify the risk associated with a specific shipment and determine the level of control required.

¹⁸ As illustrated by the OECD Trade Facilitation Indicators (TFIs), the implementation of inter-agency and cross-border co-operation remains a challenge (see Box 3.3).

¹⁹ As of October 2017, 115 notifications of suspicious shipments had been reported, enabling the seizure of one illegal shipment of pesticides (presentation JWPTE Oct 2017).

Box 3.3. Border agency co-operation: Insights from the OECD Trade Facilitation Indicators (TFIs)

Redundant or sequential controls, duplicative documentation requirements, and insufficient co-ordination among different agencies at the border can cause delays, complicate compliance by traders and strain border post resources. Border agency co-ordination thus aims to increase operational efficiency, reduce compliance costs for traders and enforcement costs for authorities, and facilitate legitimate trade.

Border agency co-operation shifts the focus beyond the traditional customs-specific trade facilitation agenda to a new and more comprehensive “whole-of-government” approach to reform. This new approach relies less on institution-specific reform and more on a wider trade supply chain approach designed to tackle the major issues traders face in navigating regulatory requirements.

Yet significant implementation challenges remain, as highlighted by the OECD Trade Facilitation Indicators (TFIs). The TFIs were developed in 2012 to support governments in their efforts to improve border procedures, reduce trade costs and reap greater benefits from international trade. They currently cover the full spectrum of administrative procedures at the border for more than 160 countries across income levels, geographical regions and development stages.

The OECD TFIs highlight that there is considerable scope for further improvements in the area of border agency co-operation – both domestic and cross-border – in spite of further steps taken by a significant number of surveyed economies to promote the exchange of information and mutual assistance across agencies involved in the management of trade.

At the domestic level, practices such as sharing inspection results and coordinating risk management mechanisms continue to gain ground in countries at all levels of development. However, development of interconnected computer systems and real time availability of pertinent data that can help agencies streamline their processes and improve their interactions remains incomplete across all regions.

Co-operation with border agencies in neighbouring and third countries is even more challenging than domestic border agency co-operation. Good progress has been made worldwide on the alignment of procedures and formalities, which is under implementation in most surveyed countries. Efforts to deepen cross-border agency co-operation through automation are also underway, but a lot more can be done. Advances have been made mainly in OECD countries and mostly in harmonisation of data requirements and documentary controls. In other areas, such as co-ordination of different computer systems, risk management co-operation and systematic sharing of control results among neighbouring countries, implementation by OECD countries and other high-income economies is again significantly more advanced than in other countries surveyed.

Source: (OECD, 2018^[56]).

79. In particular, regulatory and customs authorities need to systematically exchange findings from control and investigation exercises in order to build risk-profiles, which can then be uploaded in customs risk management systems. This should include information on commonly used methods to smuggle illegal pesticides (e.g. high risks entry points and pathways, seasonal variations), and on the type of actors involved and their modes of action (e.g., common product descriptions, common features of labelling and packaging) (OECD, 2018^[10]; Food Chain Evaluation Consortium, 2015^[12]).²⁰ Some national agencies around

²⁰ Other types of information that should be recorded and periodically updated by regulatory authorities include: any pesticides or active ingredients which are particularly common targets of illegal operators; the use of any specific HS or CN codes; key words used on customs declarations and other documentation; common inconsistencies between documents and declarations (OECD, 2018^[10]).

the world are using internal communication channels and automated risk management systems to fight trade in illegal pesticides (Box 3.4).

80. Cooperation should also be encouraged between national authorities and the private sector. Closer link between custom officers and intellectual property rights (IPRs) holders, for instance, would improve detection processes, as brand owners are experts at identifying counterfeits and best positioned to monitor their value chain (Metivier and Simonelli, 2017^[57]).

Box 3.4. The “one check principle”, a successful example of inter-agency cooperation

In the Netherlands, the Dutch Food and Consumer Product Safety Authority (NVWA) is responsible for enforcing regulation related to pesticides. The NVWA is working closely with customs, the police and the Public Prosecution Service (OM) to prevent non-authorized and counterfeit pesticides from reaching the market. Pesticides control activities mainly target the Port of Rotterdam and Schiphol Airport. These four agencies are using customs communication channels to exchange operational information.

The NVWA is in charge of defining and updating risk profiles and entering indicators into the customs automated risk management system (ARMS), which can automatically assess the risks associated with a specific shipment and recommend the appropriate level of control and inspection procedure. Indicators of risks encompass the presence of an active ingredient, the use of a description for the goods or the names of importing companies that are known to be used for illegal pesticides.

Shipments that are selected by the ARMS are inspected by both custom officers and the NVWA. Customs are responsible for coordinating these combined inspections and ensuring that only one physical check is carried out, thus minimizing time loss in the logistics chain. The NVWA then communicates the outcome of its inspection to customs, in order to ensure that a shipment is not released.

Besides reducing time and costs for traders, the “one check principle” enables the different agencies responsible for the control of illegal pesticides to benefit from each other’s knowledge and expertise. The NVWA also offer training to customs officials if required.

Source: (Ing. M.H. van Diesen, n.d.^[9]).

81. Finally, new trends in trade, such as online trade, have also challenged traditional trade control policies as they complicate the detection of illegal products at the border or at the retail level. Online trade is profoundly changing the function of control authorities and forcing them to rethink their strategies. The latter will have to shift their focus to increased monitoring of the growing sale of plant protection products over the Internet.

3.3.2. How can new digital technologies help?

82. Blockchain technology can improve the monitoring and control of pesticide trade by facilitating data exchange and cooperation among participants in the pesticide supply chain and providing easy access to a range of information about the products being traded. Beyond blockchain, other digital technologies such as big data analytics and artificial intelligence (AI), offer opportunities for a better risk-management at the border, automated inspections of containers and cargos, and the monitoring of online trade.

Blockchain

83. Compared to traditional paper-based systems or centralised databases, blockchain solutions can significantly reduce the time and costs associated with information exchange

between multiple stakeholders as well as the risks of fraud, errors, and inefficiencies (Berryhill, Bourgerie and Hanson, 2018_[42]). Blockchain can bring together and connect manufacturers, transporters, customs and other government agencies, and retailers into a single platform (SigmaLedger, 2018_[58]). A shared and immutable ledger in which all supply chain participants log their activities creates a single source of trust and therefore facilitate data exchange and cooperation between them. The most appropriate type of blockchain ledger for the pesticide supply chain is perhaps a public permissioned blockchain, where only supply chain participants can record new transactions while these transactions can be transparent to everyone (e.g. consumer) (Box 3.2).

84. The integration of blockchain into the pesticide supply chain would also offer the opportunity for responsible authorities from different countries to agree on what type of data should be entered into the system at each step of the pesticide supply chain, and to potentially integrate other types of relevant digital information (e.g. pesticide registration dossier) (Figure 3.1). Quick access to key information about the products being shipped would support regulatory and control authorities in the identification of suspicious activities.

85. Finally, blockchain also enables cross-organisation automation, through the execution of smart contracts (OECD, 2019_[47]). By automating contractual processes – e.g., the terms for payment and delivery of goods – and automatically dispersing customs duties upon acceptance of goods at the border, smart contracts can further reduce the risk of fraudulent behaviour in the supply chain, and result in cost reductions and efficiency gains for all parties involved (OECD, 2019_[47]; Law, 2017_[59]; Tripoli and Schmidhuber, 2018_[49]).

Big data analytics

86. Some customs agencies around the world are already using big data as part of their risks analysis and fraud identification efforts (Jouanjean, 2019_[41]; Okazaki, 2017_[45]). Big data enables customs structured data accumulated over time (e.g., data on investigation findings and risk profiles) to be enriched with new types of data from a wide variety of sources (e.g. intelligence on other criminal activities, data from sensors and collected by the Internet of things), thereby offering more accurate and complete information on the nature and the level of risks customs agencies are facing. In particular, by combining and correlating different categories of data – such as international trade data, government and industry data – big data techniques can estimate the risk that an actor is engaged in some form of illegal practice or quickly flag a high-risk cargo with greater accuracy (Trase, 2016_[60]) (Okazaki, 2017_[45]). These decision-making and predictive intelligence tools can thus assist customs staff by recommending priority pesticide shipments for inspection and the type of control procedures they should carry out, allowing greater prioritisation in the allocation of limited custom resources. Ultimately, the integration of big data into customs risk management systems can enable border authorities to continue fulfilling their monitoring mission, despite increasing trade flows (Jouanjean, 2019_[41]).

87. Big data analytics are already being used as a tool for fighting environmental crimes, including illegal timber, fisheries and wildlife trade (Trase, 2016_[60]; Dick et al., 2015_[61]) (Dick et al., 2015_[61]). The Environmental Investigation Agency (EIA) has been pioneering in the integration of big data solutions to form the basis of predictive analytics. Since 2006, the EIA has been using the IBM big data system to tackle illegal trade in endangered species and ivory. The system brings together field reports from EIA's investigations and old case files, government, press and research reports, and information on enforcement actions worldwide into a single database. It also has the ability to integrate visual content into the search, such as video and photographic documentation. This tool has

helped the EIA to investigate cases more effectively by providing comprehensive information on key criminal players and their prioritized targets (Davies, 2013_[62]).

Artificial intelligence (AI)

88. Artificial intelligence also has the potential to improve customs border management and fraud identification. AI robots can perform inspections on hazardous goods and can handle repetitive tasks, such as monitoring containers and warehouses, thereby freeing customs staff to conduct other tasks. AI systems can also be trained to detect risks more effectively in conjunction with other technologies, including sensors. Ultimately, automation could enable the monitoring of 100% of pesticide cargo, dramatically reducing the probability that illegal products cross the border and enter the market (Jouanjean, 2019_[41]).

89. Moreover, due to their ability to process verbal, visual and audio-visual content, AI methods such as machine learning and visual recognition algorithms can be used to monitor illegal trade on the Internet. AI systems could be trained to detect illegal pesticides offered on online platforms, based on specific characteristics of labels and packaging, or common names or product description that are known to be used for illegal pesticides. Mainstream online retail companies such as Amazon and Alibaba are already using these techniques to identify and remove fake ads and counterfeit products from their platforms (Incisive Business Media Limited, 2019_[63]). Until recently, analysing platforms or websites for evidence of illegal products required specially trained staff and a prohibitively large amount of time. AI-supported approach can dramatically reduce the time needed to identify posts that contain evidence of illegal activity, as they can quickly sift through thousands of images and textual data (Di Minin, 2018_[64]).

3.3.3. Challenges to the implementation of new digital technologies

90. The main challenge for supply chain cooperation through blockchain is perhaps the current lack of interoperability between blockchain platforms, which prevents data sharing and access between separate networks.²¹ In order to create a blockchain system to track trade in pesticides, all public and private actors involved in the journey of products would have to agree on common technical standards – e.g., on how data should be shared and stored – and ensure the interoperability of their systems. Creating a standard data model for the pesticide supply chain is likely to involve numerous and lengthy discussions among participants (OECD, 2019_[47]).

91. Supply chains actors would also have to reach an agreement on sharing the costs for developing the necessary IT infrastructure and on the mode of governance of the platform – e.g., entry and exit of participants, validation of transactions, roles and responsibilities of nodes. Getting all stakeholders involved and aligned is likely to be challenging, given the global nature and the large number of participants in pesticide supply chains (OECD, 2019_[47]).

92. Finally, the low usability of existing interfaces for blockchain ledgers – including the poor user experience, the low system speed and the lack of formalized blockchain protocols – also hinders a widespread understanding and adoption of the technology (World Economic Forum, 2018_[51]). This complexity, and the current lack of education on

²¹ There are currently hundreds of blockchain networks in operation and development, each identifying and collecting information differently, with different governance structures (OECD, n.d._[44]).

blockchain technology, means that the process of integrating all actors in pesticide supply chains onto a blockchain is likely to be challenging and to take time (Tripoli and Schmidhuber, 2018_[49]) (Berryhill, Bourgerly and Hanson, 2018_[42]).

93. The adoption of big data and AI by custom agencies also presents some challenges. First, as with blockchain, the technical infrastructure and software costs of these technologies are high – estimated at about USD 180 000 for a big data solution (Cooladata, 2019_[65]). Moreover, customs agencies would have to hire knowledgeable experts to manage these complex tools.²² To ensure broad understanding and acceptance of these new technologies, investment in training is also necessary to improve the skills and capacity of the general customs staff (Okazaki, 2017_[45]; Bekker, 2019_[66]). These substantial costs represent a barrier to the adoption of these technologies, especially in developing countries where financial resources for qualified staff and equipment at borders are limited.

94. Other challenges linked to the adoption and use of big data and AI include the complexity of managing the quality of raw data, as these technologies rely on a large amount of data collected from different sources. There are also concerns related to data privacy and confidentiality and cybersecurity, suggesting that these technologies cannot be put in place without a solid legal framework (Okazaki, 2017_[45]).

²² Human resources are considered to be the most prominent costs for building big data solutions because of existing shortages of talent that lead to increase in salaries in the big data industry (Harvey, 2017_[70]).

4. Policy responses beyond new digital technologies

95. While new digital technologies hold significant promise for supporting policy actions on traceability and authentication, and the monitoring and control of trade, other policy responses are also necessary to efficiently crack down on trade in illegal pesticides. Digital-based solutions alone are insufficient to address this issue.

96. First, raising stakeholder awareness is key in fighting trade in illegal pesticides (Malkov, Prischepa and Kutonova, 2015_[22]). Currently, actors along all stages of the pesticide supply chain are not sufficiently aware of the issue of trade in illegal pesticides to enable an effective crackdown on this criminal activity (Mace and Luda di Cortemiglia, 2016_[2]). Education and training on the risks associated with such products and how to identify them need to be provided to supply chain participants and end users through public-private collaboration. This would contribute to a higher rate of detection and seizure of illegal products throughout the supply chain and help to reduce farmers' demand for cheap, un-authorised pesticides (Malkov, Prischepa and Kutonova, 2015_[22]).

97. While new digital technologies may allow for the identification of criminal actors, strengthening sanctions for illegal pesticide offences and ensuring better law enforcement are also required to reduce the attractiveness of these criminal activities. So far, trade in illegal pesticides has been associated with minor legal, including criminal, and financial consequences (Mace and Luda di Cortemiglia, 2016_[2]). Penalties vary markedly by country, but most countries have inadequate penalties that poorly reflect the threat that these products pose to agriculture, the environment, human health and the economy (Mace and Luda di Cortemiglia, 2016_[2]; Moss, 2013_[67]). Increasing the sanctions themselves, as well as the extent to which they are applied, would provide a measure of deterrence on illegal actors (Mace and Luda di Cortemiglia, 2016_[2]).

98. Finally, there is a need to close loopholes in different pieces of legislation governing trade in pesticides. The lack of clarity and harmonisation in legislation has made it relatively easy for criminals to route their products to farmers. For instance, the legal framework governing in-transit consignments (i.e., consignments passing through non-destination countries) is often considered too weak or ambiguous to allow customs authorities to seize illegal shipments of pesticides (OECD, 2011_[1]).²³ Legally allowing customs to stop and test products in transit – based on false or incomplete documentation or strong suspicion of the illegal nature of the shipment – could prevent illegal pesticides from entering the market. Simplified customs procedures around small packages have also resulted in the release of some illegal products into the market (Europol/OHIM, 2015_[38]).²⁴

99. Legislation governing the waste management of seized counterfeit pesticides also needs to be reviewed. In most OECD countries, rules are such that the brand owner – i.e.,

²³ There is often a lack of clarity on whether consignments passing through third-countries are considered to be in the market in those territories, which affects the ability of authorities to take action or the range of actions that can be taken (OECD, 2018_[10]).

²⁴ In the EU for instance, Regulation 608/2013 requires customs to notify the brand owner to check whether goods detained are genuine or counterfeit. If brand owners do not reply within a given period, the goods can be released into the EU. However, rights-holders often do not bother to take action if the amounts seized are low (Europol/OHIM, 2015_[38]).

the IPR holder – is responsible for the storage, disposal or destruction of seized counterfeit pesticides. However, due to the high compliance costs of these liabilities, pesticide companies have asked enforcement agencies to stop seizing products infringing their trademark. Consideration should therefore be given to the introduction of legal provisions or mechanisms for the financing of these activities, including cost-sharing between brand owners and authorities (OECD, 2019^[28]).

100. In order to prevent abuse of parallel imports via free trade zones (FTZs), it may also be necessary to rethink the current legal framework surrounding parallel imports and the repackaging of pesticide products (Food Chain Evaluation Consortium, 2015^[12]).²⁵ One possible solution would be to impose “double labelling” to facilitate the traceability of repackaged products - i.e., to require the inclusion of a copy of the original label on the repackaged pesticide or indication of the original batch number (OECD, 2018^[10]). Another option could be to completely forbid the repackaging of pesticides for parallel imports (ECPA, 2008^[25]).

101. Finally, online sales of pesticides are incompletely regulated and e-commerce websites often provide very little information on the legal requirements for trading agricultural and food products (Jouanjean, 2019^[41]). The British Pest Control Association and the Crop Protection Association have recently been working with eBay and other internet companies to stop online sales of unauthorised pesticides. As a result, eBay clarified its policies for the sale of pesticides and prohibited person-to-person sales. Only authorised eBay shops are now allowed to sell pesticides on the platform (British Pest Control Association, n.d.^[68]).

²⁵ See OECD Recommendation on countering illicit trade in FTZs (OECD, 2019^[71]).

5. Conclusion

102. This paper has explored the potential of blockchain and other new digital technologies to support policy action to tackle trade in illegal pesticides. It has also discussed the challenges associated with the adoption of these technologies and provided examples of their application in other relevant areas.

103. The adoption of blockchain by participants in the pesticide supply chain would provide end-to-end product traceability, chain of custody, and access to real time information about the products being traded. This would allow for the rapid identification and reporting of problems within the supply chain, significantly reducing opportunities and incentives for fraud. Moreover, farmers would be able to easily verify a product's authenticity and provenance, enabling more informed purchasing decisions. It would also offer the opportunity for regulatory authorities from different countries to harmonize data requirements for trading pesticide products and to upload other types of relevant digital information into a shared system, facilitating the work of border and other control agencies.

104. Big data analytics and AI can also improve the effectiveness of trade control policies for pesticide products. Big data can improve risk management processes at the border, enabling quick and accurate identification of illegal pesticide shipments. Automation would also significantly reduce the risks of entry of illegal pesticides, by making it possible to physically check 100% of the cargo. Moreover, AI methods such as machine learning and visual recognition algorithms could be used to monitor the increase in illegal pesticides on online platforms.

105. While holding great promise, the adoption of blockchain, big data and AI comes with a number of challenges. Among these, the substantial upfront costs associated with these emerging technologies – including the high costs for IT development and infrastructure – and their complexity are hindering widespread deployment. In developing countries – where financial resources for equipment and skilled staff may be more limited, and the quality of the IT infrastructure can be lower – these challenges are even more acute.

106. Finally, tackling trade in illegal pesticides will require the implementation of other policy actions beyond new digital technologies. These include raising awareness among supply chain actors about the risks associated with illegal pesticides and providing training on how to identify them. Strengthening sanctions for illegal pesticide offences is also required to provide greater deterrence to illegal actors. Lastly, it is necessary to review the legal framework governing trade in pesticides in order to close loopholes currently being exploited by illegal actors to route their products to farmers.

107. Future research could focus on gathering more information about the current use of digital technologies for tackling illegal trade in pesticides, perhaps through industry surveys. This would allow a comparison of the benefits of using these technologies compared to traditional alternatives (e.g. older risk management and automation tools) in terms of detection rates (effectiveness) and cost and resource savings (efficiency). Once this baseline data and analysis were done, economic modelling research could focus on optimising the design of these systems to support policy development and investment in modernising market monitoring systems.

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