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Digital Technologies for Better Enforcement of Waste Regulation and Elimination of Waste Crime

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Abstract

Waste crimes create social and economic issues, but perpetrators perceive these crimes as minimal risk. Detection of violations and enforcement of these laws helps to ensure compliance, in turn reducing the environmental and health impacts of waste crime. The adoption of digital technologies helps to facilitate data-driven decision-making and process optimisation of governments' efforts to promote and monitor compliance and to respond to non-compliance. OECD member country governments are adopting the use of digital technologies to collect and use data to improve enforcement of their waste laws. This paper reviews the types of waste crimes that inhibit resource productivity and the transition to a circular economy, policy responses to address these crimes, and opportunities for governments to use digital technologies to enhance the effectiveness of their policies.

To date, digitalisation efforts have focused on the digitalisation of data and information exchange rather than on its transformation and use for intelligence-led enforcement actions. Examples of digital technologies currently in use include online platforms such as websites that provide integrated compliance and enforcement information about regulated activities, and electronic databases collecting information and verifying data on waste shipments and balances. Artificial intelligence systems (AI) have thus far been used sparingly, but greater connectivity of digital tools and application of AI could leverage predictive analytics, integrating deep learning to improve satellite imagining, and inform compliance monitoring and responses to non-compliance.

Keywords: circular economy, resource efficiency, digital technologies, Illegal Behaviour and the Enforcement of Law,

JEL Codes: L22, L23, O14, K42

Résumé

Les délits liés aux déchets créent des problèmes sociaux et économiques, mais leurs auteurs les perçoivent comme un risque minime. La détection des violations et l'application de ces lois contribuent à garantir le respect de la législation, ce qui permet de réduire les incidences de la criminalité liée aux déchets sur l'environnement et la santé. L'adoption des technologies numériques facilite la prise de décision fondée sur les données et l'optimisation des processus dans le cadre des efforts déployés par les pouvoirs publics pour promouvoir et contrôler la conformité et pour réagir en cas de non-conformité. Les gouvernements des pays membres de l'OCDE adoptent l'utilisation des technologies numériques pour collecter et utiliser les données afin d'améliorer l'application de leurs lois sur les déchets. Ce document passe en revue les types de délits liés aux déchets qui entravent la productivité des ressources et la transition vers une économie circulaire, les réponses politiques pour lutter contre ces délits et les possibilités pour les gouvernements d'utiliser les technologies numériques.

Jusqu'à présent, les efforts de numérisation se sont concentrés sur la numérisation des échanges de données et d'informations plutôt que sur leur transformation et leur utilisation pour des actions de contrôle fondées sur le renseignement. Parmi les exemples de technologies numériques actuellement utilisées, on peut citer les plateformes en ligne telles que les sites web qui fournissent des informations intégrées sur la conformité et l'application des activités réglementées, et les bases de données électroniques qui recueillent des informations et vérifient les données sur les transferts et les bilans de déchets. Les systèmes d'intelligence artificielle (IA) ont jusqu'à présent été utilisés avec parcimonie, mais une plus grande connectivité des outils numériques et l'application de l'IA pourraient tirer parti de l'analyse prédictive, en intégrant l'apprentissage en profondeur pour améliorer l'imagerie satellitaire, et informer le contrôle de la conformité et les réponses à la non-conformité.

Mot clés: Économie circulaire, efficacité des ressources, technologies numériques, Comportement illégal et application de la loi

Classification JEL: L22, L23, O14, K42

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Acronyms

AI	Artificial intelligence
API	Application Programming Interface
CBSA	Canadian Border Service Agency
CNMTS	Canadian Notification and Movement Tracking System
DG	Directorate-General
ECCC	Environment and Climate Change Canada
ECHO	Enforcement and Compliance History Online
EDM	Electronic Data Management
EEE	Electrical and Electronic Equipment
EO	Earth Observation
EOL	End-of-Life
EPA	Environmental Protection Authority (New Zealand)
EPOC	Environment Policy Committee
EU	European Union
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
ICT	Information and Communication Technology
IEDC	Intercambio Electrónico de Datos de Notificación y Consentimiento
ILT	Netherlands Inspectorate for Human Environment and Transport
IoT	Internet of Things
JSON	JavaScript Object Notation
IMPEL	EU Network for the Implementation and Enforcement of Environmental Law
LEA	Law Enforcement Agency
MLA	Mutual Legal Assistance
NCEDE	Notice and Consent Electronic Data Exchange
OECD	Organisation for Economic Co-operation and Development
OPFA	Operational Facility
PIC	Prior Informed Consent
RCRAInfo	Resource Conservation and Recovery Act Information
R/D	Recycling / Disposal
SEMARNAT	Secretaría del Medio Ambiente y Recursos Naturales
UNEP	United Nations Environment Program
UNODC	United Nations Office for Drugs and Crime
UK	United Kingdom
U.S. EPA	United States Environmental Protection Agency
WEEE	Waste Electrical and Electronic Equipment
WIETS	Waste Import Export Tracking System

Executive Summary

Governments set policies to reduce waste generation and minimum requirements for the environmentally sound management of waste that waste managers cannot recover. These policies help to enable a transition to a circular economy, which minimises waste and maintains material value and inputs. Detection of violations and enforcement of these laws helps to ensure compliance, in turn reducing the environmental and health impacts of waste crime.

Waste crimes create social and economic issues, but perpetrators perceive these crimes as minimal risk. Waste crimes can pollute the air, soil and water, impact and damage ecosystems and be dangerous for human health. Crime can be profitable, due to the avoidance of costly waste management practices. If the perceived risk of detection and punishment is low, there can be an economic incentive to engage in waste crime. Waste laws can also be complicated and vary by jurisdiction, confounding compliance by regulated entities.

Governments pursue an integrated approach to promote and monitor compliance and to respond to non-compliance. Compliance promotion aims to make regulated actors aware of the rules and of their requirements in order to prevent cases of non-compliance. Monitoring involves collecting information on the performance of the waste management industry to evaluate how regulated entities implement environmental provisions and if requirements are met. In cases of non-compliance, governments compel the offender to return to compliance, remediate the damage resulting from the violation, and impose sanctions. Governments pursue a combination of these approaches to detect and deter non-compliance with waste laws.

Barriers to compliance promotion and enforcement include legal framework challenges, rapid changes in waste management practices, and limited resources and data. The classification of waste streams is key to identify which requirements apply for its movement and/or treatment circumstances. Recent changes in international agreements, and differences in classifications by different government entities complicate compliance and monitoring. Governments also have limited budgetary resources constraining their ability to promote compliance with awareness raising and enforcement. There is also a general lack of data on waste crime which makes it difficult for governments to discern patterns and make effective use of limited budgetary resources.

The adoption of digital technologies helps to facilitate data-driven decision-making and process optimisation. OECD member country governments are adopting the use of digital technologies to collect and use data to improve enforcement of their waste laws. The OECD adopted a Recommendation of the Council on Information and Communication Technologies and the Environment in 2010 to strengthen the important and increasing role of these technologies in resource sustainability (OECD, 2010[1]).The most common technologies that governments currently use include:

- Online platforms which help increase transparency and enable easier accessibility to information. For example, websites providing integrated compliance and enforcement information about regulated activities nationwide support governments in their compliance promotion efforts and enable citizens to report violations.
- Cradle-to-grave databases and forensic data collection tools that improve traceability and facilitate compliance monitoring. For instance, electronic databases collecting information from point of

generation to transport, disposition and export, enable tracing waste and verifying data on waste shipments and balances. Forensic research and predictive analytics both build on historical enforcement data (e.g. previous cases of waste trafficking) to identify future outcomes (e.g. future cases of waste trafficking) and thereby contribute to increasing the success rate of inspections (i.e. by identifying which sites and facilities to inspect).

- Remote sensing and drones equipped with lasers, which are in use sparingly, have potential to ensure intelligence-led investigations and prosecution of waste crime. Drones with laser technology have proven effective in evaluating volumes of illegal dumps and calculating costs for clean-ups.
- Artificial intelligence (AI) systems which help governments to target their efforts and overcome limited budgetary resources. In several countries, machine learning algorithms applied to satellite imagery have reduced investigation time and increased cost effectiveness in detecting illegal waste sites, compared to manual methods.

However, legal, technical, and financial challenges have inhibited governments' efforts to digitalise. These include the lack of legal clarity on how, by who and under what conditions certain technologies can be used (such as in cases of surveillance and evidence to courts), the need to develop scripts and algorithms to improve pattern recognition (for instance of illegal waste sites), weak interoperability of governmental systems and exchange of data, as well as relatively high cost of purchasing some of the technologies.

To date, digitalisation efforts have focused on the digitalisation of data rather than on its transformation and use for intelligence-led enforcement actions. Major gaps in exchange and linking of data and databases (across national authorities, between various levels of government, and internationally) prevail, while there is less experience with using data for analytical purposes. Efforts to date are helping to create a sufficient mass of digital data that could be used in the future to train artificial intelligence (AI) tools. Whilst the integration and connection of various digital tools is a gap, the full potential of digitalisation remains underutilised.

There is enormous potential for AI to increase compliance, monitoring of compliance, and response to non-compliance. Greater connectivity of digital tools and application of AI could leverage predictive analytics, integrating deep learning to improve satellite imagining, and inform compliance monitoring and responses to non-compliance. Ultimately, it can help to leverage capacities and direct the use of limited resources to target governments' effort more efficiently. In a second phase of digitalisation, once processes are in place to collect and store relevant data digitally, efforts should focus on expanding the use of this data for compliance promotion and improved risk assessment.

1 Introduction

A resource efficient circular economy[1] is one in which maintains material value and minimises material inputs and waste. A circular economy keeps resources flowing within rather than through the economy, modifying flows of products and materials by means of three main mechanisms: closing resource loops, slowing resource loops or flows, and narrowing resource flows (Mcarthy, Dellink and R. Bibas, 2018[2]).

Waste management laws are critical components of the transition to a circular economy. Policies to enable this transition set requirements or incentives for waste reduction, and re-use and recycling. Governments also set policy for environmentally sound management of waste that waste managers cannot recover[2]. Laws at numerous government levels set the requirements for regulated actors for waste management practices.

Enforcement of waste management laws helps to ensure compliance by the regulated actors. Monitoring and enforcement actions are key tools to assess and improve environmental compliance by waste management operators. Yet, compliance assurance has long been subject to little attention, in contrast with the design of specific policies and tools (OECD, 2009[3]). Ensuring enforcement of and compliance with environmental laws has been undermined by challenges in detecting and taking action against non-compliance, defining clear standards, and ensuring that laws are tailored to national and local contexts, that there is coordination across government agencies and that the implementing ministries are not underfunded and politically weak (UNEP, 2019[4]; OECD, 2009[3]).

Governments can stand to improve their enforcement and compliance monitoring of their waste laws by applying and integrating digital data and tools. For example, the OECD Regulatory Enforcement and Inspections Toolkit highlights information integration as one of twelve criteria (OECD, 2018[5]). Information and communication technologies (ICTs) can focus on risks to promote co-ordination and information-sharing and ensure an optimal use of enforcement resources. Therefore, improvements in the use of data and information, which digitalisation can generate, help to enforce waste laws and the transition to a circular economy. The OECD adopted a Recommendation of the Council on Information and Communication Technologies and the Environment in 2010 to strengthen the important and increasing role of these technologies in resource sustainability. The recommendation includes adopting lifecycle perspectives, developing green ICT skills, and encouraging best practices (OECD, 2010[1])

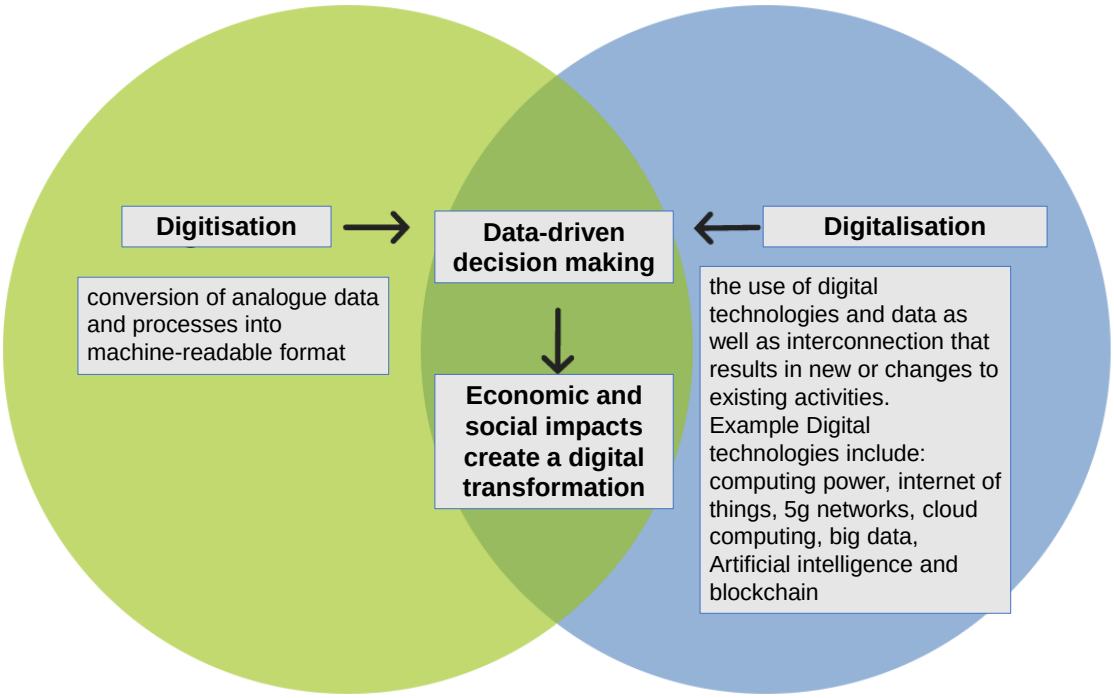
The digital transformation is the cumulation of the societal and economic impacts of digitisation and digitalisation. (Figure 1.1). Digitalisation of the production of goods and services transforms economies and societies by changing the way people interact with physical and virtual assets, how businesses function and innovate, and how governments design and implement policies (OECD, 2019[6]). More specifically, digital technologies facilitate data-driven decision-making. They allow optimisation of systems and processes performance (Barteková and Börkey, 2022[7]). Optimisation via digitalisation speeds up realising the transition to a circular economy, for example allowing technologies to collect, manage and process data and information and to create knowledge about material composition of products, their origin and

[1] For the rest of the paper, the term circular economy will be used to describe resource efficiency and circular economy processes related to lowering the rates of natural resource extraction and use throughout the value chain.

[2] The OECD hosts a recommendation on the environmentally sound management of waste, first adopted in 2004 (OECD, n.d.[74]).

properties, their location, condition, and availability, as well as their respective manufacturing processes and conditions for maintenance, dismantling and recycling (Barteková and Börkey, 2022[7]).

Figure 1.1. Model of digital transformation enabling better policy design and improved implementation



Source: based on (OECD, 2017[8]) (modified), definitions from (OECD, 2019[6]).

The OECD has previously researched digitalisation and compliance with environmental laws independently. The OECD's work on digital economy strives to understand how information and communication technologies (ICTs) contribute to sustainable economic growth and social well-being and examines trends and analyses emerging opportunities and challenges in the digital economy (OECD, 2023[9]). Evidence from previous OECD research demonstrates that the deployment of digital technologies can help users to overcome information asymmetries (Barteková and Börkey, 2022[7]). Previous OECD research identified technologies combining blockchain, artificial intelligence, cloud computing and online platforms as enablers of more effective design and implementation of circular economy policies (OECD, 2022[10]).

Previous research on environmental compliance examined strategies and instruments that governments use to ensure compliance with pollution prevention and controlling regulations (OECD, 2009[3]). The OECD also addressed the topic of illegal trade of environmentally sensitive goods, including hazardous waste (2012[11]).

More recently, the nexus of digitalisation and illegal trade analysed the potential of digital technologies to support policies tackling trade in illegal pesticides (2020[12]). Additionally, a case study of the agricultural sector in the United States highlighted how digitalisation has helped with innovative compliance measures (2019[13]).

Environmental and waste crime and the current enforcement efforts across different countries have been addressed within two reports by the United Nations Environment Programme (UNEP) (Rucevska I.,

2015[14]; Nellemann et al., 2016[15]). In terms of sector-specific evidence, the current trends in waste from electrical and electronic equipment (WEEE) and in global plastic waste have been analysed by the Interpol (2020[16]) and by Huisman et al. (2015[17]). Finally, a recent DG Environment issue paper on impacts of digital transformation on the environment also includes a case study on e-waste, which briefly touches on the potential role of digitalisation in tackling free riding on extended producer responsibility (Ran Liu, 2019[18]). Although each of these reports (at least partially) addresses the topic of enforcement, compliance, and/or waste crime, none of them reviews the key policy responses supported by digital technologies across individual countries.

OECD research on the nexus between illegal trade and waste crime states that digital technologies can help increase transparency of value chains, but they are still in early stages of their application (Yamaguchi, 2023[19]). Also, the use of digital technologies to combat cross-border environmental crime is emerging, however, they are still at a very nascent stage. They also need to be accompanied by parallel efforts to strengthen laws and regulations, to enhance law enforcement at the border, and increase regulatory awareness among the different actors including law enforcement, inspectors, and the judiciary.

There remains a research gap in identifying how OECD member country governments are using digitalisation to support detection, interdiction, and prevention of environmental crimes, including waste crime. This paper aims to answer the following questions:

- What are the types of waste crimes that inhibit resource productivity and the transition to a circular economy? (chapter 2)
- What are the policy responses to address these crimes? (chapter 3)
- How can digitalisation enable OECD countries to implement these policy responses? (chapter 4)

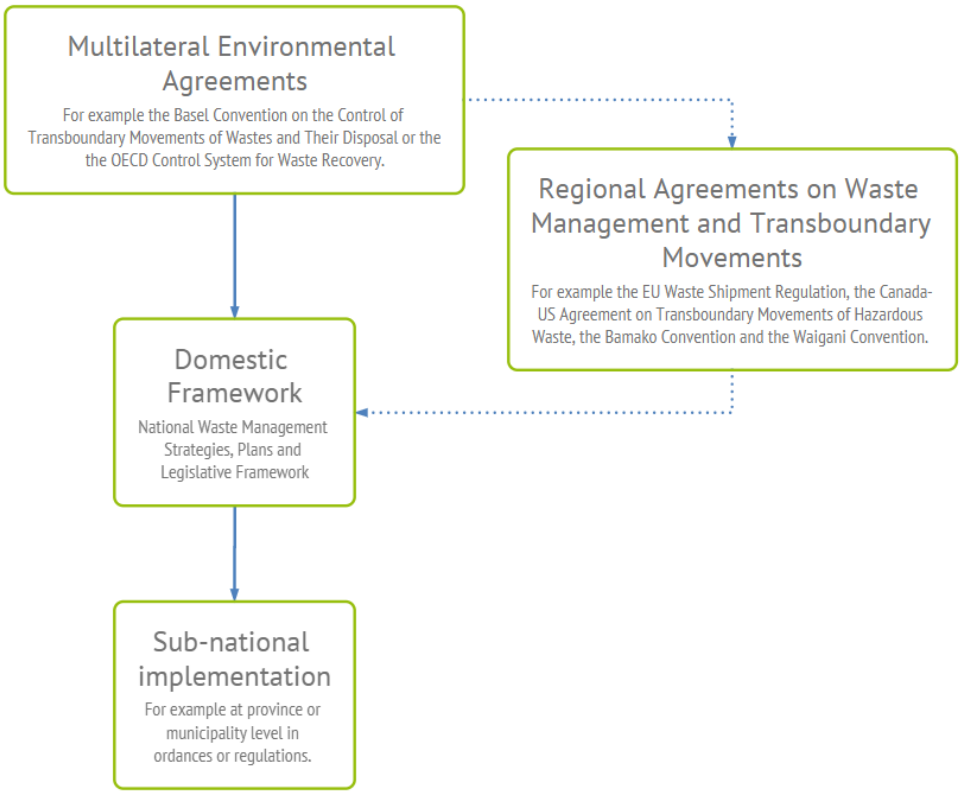
Desk research and a series of interviews with OECD country government officials informed the findings outlined in this paper. The desk research informed the background information about existing research and applications of digital tools related to waste crime. The semi-structured interviews were held with representatives from governmental organisations involved in permitting processes for waste management operations, inspections, and investigation of cases of waste crime.

2 Waste crime

Policy that enables the transition to a circular economy supports reuse, repair and recycling and avoids the generation of waste by transforming it into secondary raw materials. Often, national waste management strategies include these policies. Governments set the framework for waste management to increase resource productivity and recovery and to reduce negative environmental and health impacts of waste.

Detecting violations of these policies is integral to ensuring that they are effective. International agreements contain the principles and provisions for transboundary movement and environmentally sound management of waste, which are in turn implemented into regional and domestic legislative frameworks and often performed by municipalities or at the sub-national level (Figure 2.1). These provisions concern waste generation in general (i.e. requirements for classification, minimum treatment standards and recycling targets) and hazardous waste more specifically (i.e. special requirements for transport and treatment), as well as waste disposal (i.e. collection and treatment options) and shipment (i.e. record-keeping and cross-border regulations).

Figure 2.1. Overview of the implementation of waste management provisions



At the international level, there are two important multilateral agreements concerning waste trade, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (hereafter the Basel Convention), and the OECD Control System for waste recovery, embodied in the OECD Decision of the Council on the Control of Transboundary Movements of Wastes Destined for Recovery Operations (OECD/Legal/0266). The two international agreements are however closely interlinked, and the waste categorisations under the OECD Decision are generally harmonised with the waste lists in the annexes to the Basel Convention.

The main global agreement dealing with the management and transboundary movements of waste, is the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and Their Disposal (hereafter Basel Convention)[3]. Provisions refer to environmentally sound management of waste, minimisation of waste, waste classification and to regulating the transboundary movements of waste. This latter is done via the Prior Informed Consent Procedure (PIC), with strict requirements for transboundary movements of hazardous wastes and other wastes. The procedure forms the heart of the Basel Convention control system and is based on four key stages (1) notification; (2) consent and issuance of movement document; (3) transboundary movement; and (4) confirmation of disposal. Considering the changes to the Basel Convention expanding its scope to hazardous and mixed plastic waste[4] and the recently adopted amendments[5] to the Basel Convention regarding requirements for electrical and electronic waste, the debate on enforcement and compliance with waste regulation has received increased attention of both domestic and international policymakers.

The OECD Decision aims at facilitating the trade of waste destined for recovery that can be recovered in an environmentally sound and economically efficient manner, by using a simplified procedure as well as a risk-based approach to assess the necessary level of control for materials. Wastes exported outside the OECD area, whether for recovery or final disposal, do not benefit from this simplified control procedure. Rather, the transboundary movement of such wastes is likely to be covered by the Basel Convention.

The legal and practical implementation of international agreements is the responsibility of the individual countries. Implementation measures at the national level can include adopting or modifying policies, legislation, resources and, if needed, institutional changes. In some countries, national waste management can be further decentralised towards a state, regional or local level. For instance, the responsibility to issue permits for operators of waste treatment facilities may be delegated by the national government to a regional or local authority.

Waste crime and its socio-economic impacts

Environmental crimes pose a present and ongoing threat to public health and the environment. Environmental crimes can occur across border and range from poaching and trafficking of protected species to illegal disposal of hazardous waste.

There is an increased sense of urgency to combat environmental crime as data suggest that the amount of criminal activity is growing. Whilst the possible annual growth rate of environmental crimes is difficult to estimate, an analysis based on registered trade statistics, seizures and reported incidents including of

[3] The Basel Convention came into force in 1992 and as of April 2023, has 190 Parties to the Convention.

[4] The fourteenth meeting of the Conference of the Parties to the Basel Convention (COP-14, 29 April–10 May 2019) adopted amendments to Annexes II, VIII and IX to the Convention with the objectives of enhancing the control of the transboundary movements of plastic waste and clarifying the scope of the Convention as it applies to such waste.

[5] The fifteenth meeting of the Conference of the Parties to the Basel Convention (face-to-face segment of COP-15 , 6-17 June 2022) adopted amendments to Annexes II, VIII and IX to the Convention with the objectives of enlarging the control of transboundary movements of e-waste and making all electronic and electrical waste subject to the prior informed consent (PIC) procedure.

iconic species and chemicals, estimated that in the last decade there has been a rise in environmental crimes by an annual growth rate of possibly in the range of at least 5–7%, with examples as high as 21–28% (UNEP-INTERPOL, 2016[20]). When compared to a global GDP growth rate of 2.4%, this implies that the growth rate in environmental crimes, including the illegal wildlife trade, may be 2–3 times that of the global economy.

Waste crime is a subcategory of environmental crime. The impact of crimes committed with waste, induces an estimated USD 10-12 billion annually in losses (UNEP-INTERPOL, 2016[20]).

There is no universally accepted definition of *waste crime*. The Basel Convention contains a definition of illegal traffic in waste[6]. The United Nations Office for Drugs and Crime (UNODC) previously defined waste crime, in a broad manner, as conduct that relates to waste and is criminalised (UNODC, 2022[21]). For the purposes of this paper, waste crime is the trade, treatment or disposal of waste in ways that breach international or domestic environmental legislation.

The meaning of *waste offences* may vary depending on the context. In some contexts, waste offences is a broader term, consisting not only of criminal offences relating to waste but also including civil and administrative offences. *Waste trafficking* is also a term that may have different definitions, ranging from narrower definitions that focus on the illegal movement of waste and, in particular, the illegal transboundary or transnational movement of waste, to more expansive definitions that encompass a broader range of illegal acts. Waste trafficking is thus a subset of waste crime and waste offences, a subset of varying breadth depending on how the term is used. For the purpose of this report waste trafficking refers to illegal transboundary movements of waste.

Entire communities are affected by waste crimes, since the risks and impacts of improper shipments and management of waste can be far-reaching, including impacts on the environment, health, and the economy (Figure 2.2). Waste crimes can pollute the air, soil and water, impact and damage ecosystems and be dangerous for human health. As an example, the rapidly increasing levels of plastic waste generation and mismanagement, pose a serious global environmental problem that jeopardises not only human health directly, but also indirectly through the food chain (Abdullah Al Mamun, 2023[22]). As well, illegal exports of e-waste followed by improper treatment result in the emission of contaminants, such as heavy metals (Farmer, 2015[23]).

[6] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, Article 9 – Illegal Traffic reads as follow:

1. For the purpose of this Convention, any transboundary movement of hazardous wastes or other wastes:

(a) without notification pursuant to the provisions of this Convention to all States concerned; or

(b) without the consent pursuant to the provisions of this Convention of a State concerned; or

(c) with consent obtained from States concerned through falsification, misrepresentation or fraud; or

(d) that does not conform in a material way with the documents; or

(e) that results in deliberate disposal (e.g. dumping) of hazardous wastes or other wastes in contravention

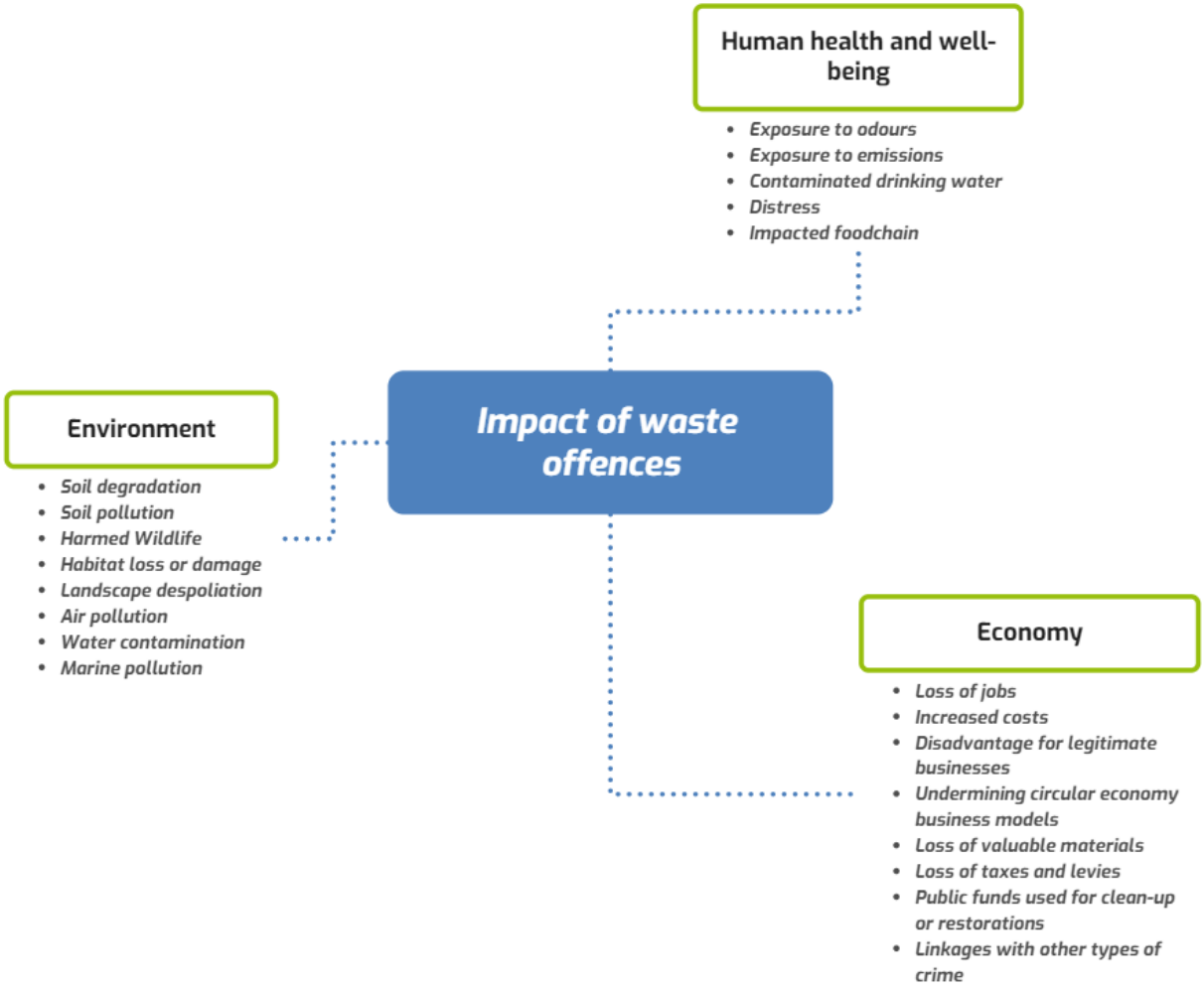
of this Convention and of general principles of international law, shall be deemed to be illegal traffic.

[…]

5. Each Party shall introduce appropriate national/domestic legislation to prevent and punish illegal traffic.

The Parties shall co-operate with a view to achieving the objects of this Article.

Figure 2.2. Negative impacts of waste and related offences



Source: Environmental Compliance Assurance Guidance Documents – Combating Environmental Crimes and Related Infringements, European Commission (2021) modified

Waste crimes also have social and economic secondary effects. Other side effects of waste crime relate to the loss of valuable resources due to improper or inefficient treatment (Huisman, 2015[17]), loss of revenue for governments or additional costs for clean-ups and restoration projects (UNEP-INTERPOL, 2016[20]) and loss of public trust in the governments' ability to deal with waste (Sam Taylor, 2014[24]).

Drivers behind waste crime

To tackle and eliminate waste crime or to correct non-compliance behaviour, it is key to understand the motivations behind the behaviour.

Economic incentive is the main factor that makes waste vulnerable to offences and crime. Because proper waste management can be costly, especially in those cases when waste has a negative value, there can be an incentive to dispose of waste outside the legal framework to avoid or reduce costs. Legal and safe

treatment is likely to be more expensive due to the requirements and standards which tend to be costlier, than illegal or improper treatment.

A low expectation of detection due to *weak regulatory enforcement* can drive waste crime. Committing waste offences is perceived to be minimal risk, as the chance of getting caught is low and, even if detected and prosecuted, the fines and penalties are low. On the other hand, the financial gains are high when the crimes remain unnoticed.

Lack of clear provisions and legal definitions can also provide a window of opportunity for illegal behaviour, enabled by gaps or loopholes in the legislative frameworks. Regulated entities can face both a poor understanding of the regulations and a lack of clarity from governments to definitions of waste versus non-waste, or hazardous versus non-hazardous waste. All this can lead to (unintentional) violations of waste regulations.

International waste trade is complex, with a wide range of actors involved, various legal systems and jurisdictions, market values and coordination. This generates opportunities to conduct both legal and illegal waste management operations simultaneously, making detection a challenge.

Investigators have detected that organised criminal organisations have been involved in committing waste crimes and trafficking waste. Historical examples include extortion by organised crime in Italy, Japan, and the east coast states of the United States (Franklin-Walis, 2023[25]). In the United Kingdom, where the introduction of its landfill tax has increased the attractiveness of waste crime, a sample of 20 known organised crime groups found that 70% were linked with a business and more than half were involved in tax fraud, indicating that waste crime groups frequently operate behind limited companies specialising in money laundering (Serious and organised waste crime review, 2018[26]). Organised crime elements have engaged in the illicit trade in plastics waste via front-companies for financial crime and corruption; additionally, illicit waste shipments have been combined with trafficking of other illegal items such as drugs (Comolli, 2021[27]).

Types of waste crime

Waste crime manifests itself in different forms. Common modus operandi applied in the case of *transboundary movements of waste* are to misclassify the composition of the waste, falsely declare the waste, or to conceal its final destination. Some examples include declaring WEEE as second-hand equipment and using codes for non-hazardous waste for waste which it is in fact hazardous (Rucevska I., 2015[14]). Another common criminal method is physical concealment of waste, by hiding it during transport or mixing hazardous with non-hazardous waste (Rucevska I., 2015[14]). Documents are in those cases often falsified, such as test reports, transport documents or licences.

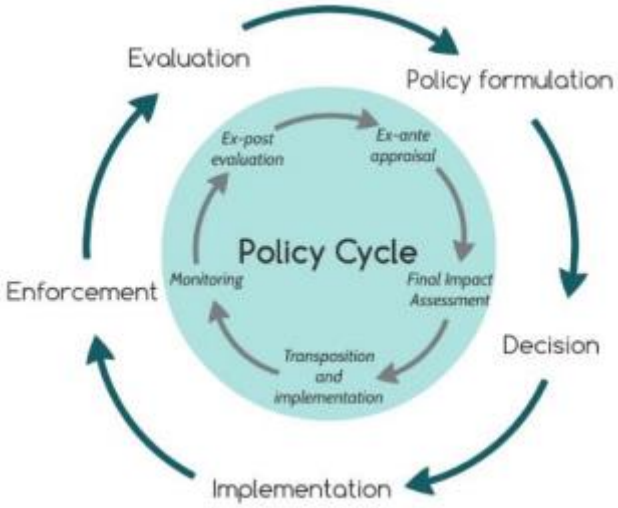
At the *domestic level*, waste offences can relate to illegal storage of waste, illegal dumping or fly-tipping, deliberate breaches of waste sites operating licenses or fraudulent producer responsibility claims. A global law enforcement action against waste crime coordinated by Interpol (INTERPOL, 2017[28]) showed that construction waste, biological and chemical waste[7] and waste related to the car industry were mostly detected at illegal waste sites, followed by e-waste, household waste, metal waste, plastic waste, oil waste and mixed materials.

[7] Chemical and biological waste includes but is not limited to wastewater, expired medicines, sludge, paint, pesticides.

3 Policy responses to improve compliance and enforcement

Implementation and enforcement of policy are key steps in the regulatory cycle (Figure 3.1). The regulatory cycle is the process that government agencies face in regulating the impact to the environment and to develop strategies to ensure compliance (IMPEL, 2018[29]). It helps to work systematically towards a permitting, compliance and enforcement programme that will include structured feedback. In the case of waste management, the goals relate to protecting the environment and human health by proper management standards, preventing and minimising the generation of waste, preserving energy and natural resources and moving towards a circular economy.

Figure 3.1. Four stages of a regulatory policy cycle (outer circle) and corresponding tools (inner circle)



Source: (OECD, 2017[30])

The implementation of policies includes measures such as design of legislative frameworks and permitting or licensing schemes. To monitor the actual implementation and level of compliance, inspection and enforcement actions should follow. Weak implementation of environmental legislation undermines the effect of legislation and the impact of policy and strategic goals.

Policy responses for better compliance and enforcement

The tools to promote and assure compliance, but also to respond to non-compliance, can be categorised into three approaches: *compliance promotion*, *compliance monitoring*, and *responses to non-compliance*[8]. Each approach requires strategic planning by governments and a clear view on the environmental outcomes.

On 8 June 2023, the Recommendation on Environmental Compliance Assurance[9] was adopted by the OECD Council meeting at Ministerial level on the proposal of the Environment Policy Committee (EPOC). The Recommendation aims to support the designing of an effective and efficient package of tools for promoting, monitoring and enforcing compliance with environmental law. It considers that compliance assurance is a crucial element of the iterative, cyclical process of environmental regulation as it links legislative requirements with the assessment of policy implementation and feedback, allowing adjustment of the legal and policy framework.

Compliance promotion

The compliance promotion approach aims to make regulated actors aware of the rules and of their required efforts in order to be compliant with applicable provisions. The overall aim is to *prevent* cases of non-compliance. This approach encourages compliance through several means, including awareness raising, information dissemination, technical assistance and guidance, toolkits, regulatory and financial incentives and rewarding good compliance.

Compliance promotion can be particularly effective if compliance monitoring and enforcement of a law is difficult. This can be the case when the regulated community is diverse, small scale and widespread. For example, to improve compliance reporting and monitoring for its extended producer responsibility requirements for plastic packaging, India's Central Pollution Control Board has established an online portal with modules for producer registration, certificate issuance and transfer (CPCB, n.d.[31]).

Compliance promotion is also useful in those cases where a lack of knowledge or understanding of the provisions in place causes non-compliance. Moreover, compliance promotion is beneficial in those cases where regulated entities exhibit resistance to enforcement (OECD, 2009[3]). For example, the Netherlands started an awareness campaign to inform exporters about a new restriction of importing countries for used vehicles (Box 3.1).

[8] The three approaches are based on INECE (2009[40]).

[9] The text of the Recommendation can be accessed here: https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0494

Box 3.1. Example of good practice on compliance promotion: Limiting the export of used vehicles from the Netherlands to Africa

A detailed assessment by the Human Environment and Transport Inspectorate in the Netherlands in 2019 showed that many of the cars and vans shipped from Dutch ports to African countries are older vehicles. They have low European emission standards and do not hold a valid roadworthiness certificate. Further test results showed that there are often technical issues with the emission control systems.

In an attempt to reduce the emissions of fine dust, NOx and CO2 from second-hand cars shipped to Africa and to limit to import of cars not meeting the safety standards, 15 African countries announced new import restrictions.

Following the changing import requirements, the Netherlands published the changed policy on their website. Exporters intending the export vehicles from the Netherlands to 15 countries in Africa were informed via the Ministry of Infrastructure and Water Management's website about the new upcoming restrictions, such as age limit for second-hand cars and Euro 4/IV vehicle emissions standard. Pro-actively informing stakeholders involved in the export of used vehicles about the upcoming revised regulations, enabled them to adjust their businesses as needed.

Source: (Human Environment and Transport Inspectorate, 2020[32]).

Compliance monitoring

Compliance monitoring is collecting information on the performance of the waste management industry to provide insight on how waste managers implement environmental provisions and if the requirements are met. This approach monitors compliance through several means, including inspections, audits and investigations, as well as self-reporting and citizen monitoring. The aims of monitoring can include assessment, evidence collection, deterrence, and provision of feedback on challenges with implementation to policymakers (US EPA, n.d.[33]).

There is a growing consensus that risk assessments and targeting should inform inspections, rather than random or ad-hoc inspections, or responding to complaints (OECD, 2009[3]). INTERPOL encourages enforcement agencies to develop an intelligence-led approach, with risk indicators that would allow officers to increase the detection rate over the same number of inspections (INTERPOL, 2020[16]). For example, the EU-wide Shipments of Waste Enforcement Action Project is using data to improve compliance monitoring (Box 3.2).

Box 3.2. Example of EU-wide Inspections of Waste Shipments

Funded through the EU LIFE-fund, the EU Network for the Implementation and Enforcement of Environmental Law (IMPEL) is implementing an EU-wide Shipments of Waste Enforcement Action Project (SWEAP). This Project aims to support the circular economy by disrupting the illegal waste trade at the EU level by:

- Increasing skill set amongst inspectors and law enforcement agencies
- Intensifying collaboration nationally and internationally
- Developing innovative tools and techniques
- Creating EU-wide inspection data set
- Providing intelligence products

As part of the project, as of March 2023, officials performed 86 000 inspections at ports, waste sites and along transport routes. As part of the project, an inspection data reporting app has been developed to collect and store data from waste shipment inspections. The app collects a wide range of data throughout the inspection chain, from the point of inspection, identification of the waste involved, to the question of whether inspectors detected a violation or not and the type of violation and sanction. Linked with the app, an Application Programming Interface (API) links to a visualisation tool (Spotfire) which enables the visualisation of the data. National authorities can also use the API to link back to their national reporting systems.

The advantage of this EU-wide tool is the harmonised collection of data, enabling comparison and use for analytical purposes. The reports can also enable reporting to the European Commission in conformity with article 51 of the Waste Shipments Regulation, and the Basel Convention Secretariat as referred to in article 13 of the Convention. Criminal intelligence can also be subsequently shared with Europol through the Project if individual authorities so wish.

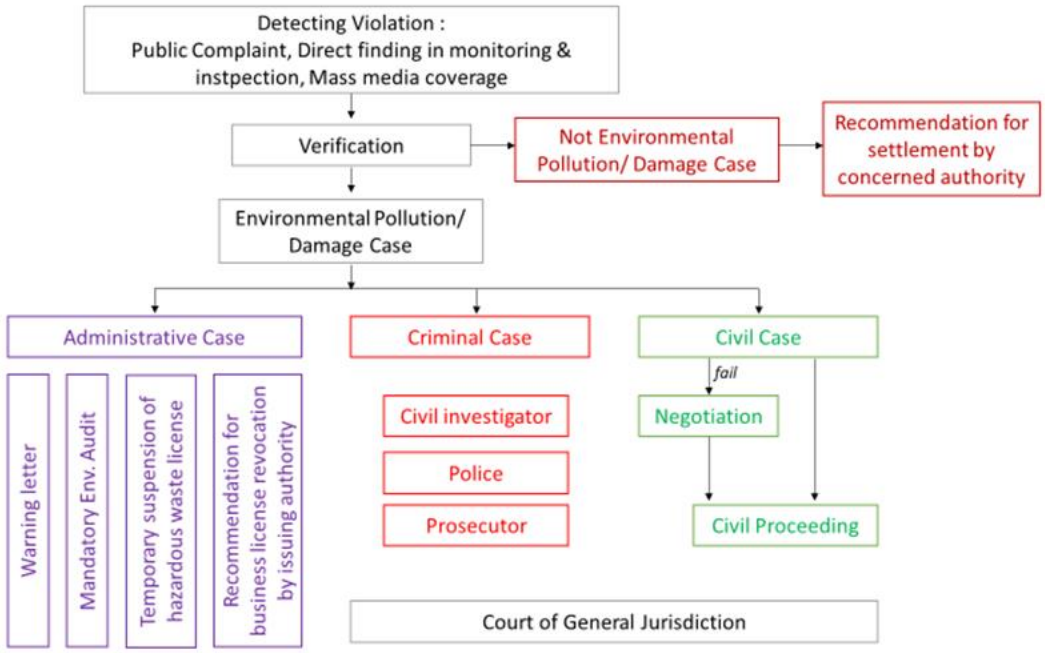
The known challenges to overcome in such inspection data collection are the data agreements between the individual countries and the authority hosting the data server.

Source: (SWEAP, n.d.[34])

Responses to non-compliance

Enforcement actions cover activities to compel the offender to return to compliance, remediate the damage resulting from the violation, and impose sanctions. Typically, there are three forms of legal liability: *administrative, criminal and civil.* The most significant difference between them is that punishments in criminal and civil legal actions are applied by judicial courts, while administrative sanctions are done through administrative procedure applied by non-judicial bodies. Governmental agencies design and monitor administrative law. This is law that regulates relations between governments and citizens. Criminal law deals with crimes and their prosecution. Civil law is the law governing the relations between private persons or organisations (WasteForce Project, 2020[35]). In the case of waste law, all three types of forms can be applied, depending on the national arrangements (Figure 3.2).

Figure 3.2. Outline of enforcement approaches



Source: (WasteForce Project, 2020[36]).

Governments must select a type of enforcement approach when responding to non-compliance. The nature and the severity of the breach should inform response selection. Guiding principles to consider focus on whether the enforcement action will be proportionate to the seriousness of the case (for example the hazardousness of the waste, intention or the created damage), and whether decisions about enforcement action will be unbiased (meaning fair, impartial, transparent and objective) and based on the strategic objectives of the enforcing authority. Irrespective the approach chosen, evidence of the non-compliance should be well documented, and arguments well presented to advance with the enforcement action. Good practice examples of different enforcement actions implemented in practice are listed in Box 3.3.

Box 3.3. Good practices of non-compliance responses

Environmental Protection Authority Prosecution Guidelines (New Zealand)

The Environmental Protection Authority (EPA) of New Zealand developed guidelines (New Zealand Government, Environmental Protection Authority, 2020[37]), which must be followed when deciding whether or not to undertake prosecutions, and in conducting prosecutions in connection with the EPA's functions. The document sets out considerations related to the evidential test (i.e. is the collected evidence sufficient to provide a reasonable prospect of conviction) and the public interest test (i.e. is prosecution required in the interest of the public). Factors include, inter alia, the seriousness of the offence, whether the case concerned premeditation, the availability of alternatives to prosecution and the history of non-compliance of the offender. It further specifies the independence of EPA staff in the process, how the EPA should deal with media and publicity and how it interacts with victims, witnesses, and defendants.

Environment Agency Enforcement and Sanction Policy (United Kingdom)

The policy paper (Environment Agency, 2022[38]) explains the results the Environment Agency aims to achieve by enforcing environmental laws. The aims of the policy are to:

- Stop illegal activity from occurring or continuing
- Put right environmental harm or damage, also known as restoration or remediation
- Bring illegal activity under regulatory control, and so in compliance with the law
- Punish an offender and deter future offending by the offender and others.

It lays down the regulatory and penalty principles, the available option and how to determine enforcement decisions. Similar to the New Zealand guidelines, the UK's policy also considers factors like risk posed to people and the environment, seriousness of the breach of the law, impact on the environment, people and legitimate business, cost of taking enforcement action against the benefit of taking it and the impact on economic growth. The focus of their regulatory effort is on the highest risks, serious environmental damage, the deliberate action and even the involvement of organised crime. In case of waste offences common responses are warnings, formal cautions, and prosecution. Depending on the offence, either a fixed penalty notice may be issued or variable monetary penalty.

Integrated approach

There are very few circumstances where a single policy instrument is likely to be the most efficient or effective way to address an environmental challenge (OECD, 2004[39]). A combination of interventions discussed above is more effective (INECE, 2009[40]). The development and implementation of an integrated approach necessitates, inter alia, an appropriate legal framework that lays down tasks, responsibilities and mandates for the authorities involved (see example in Box 3.4). Additionally, it requires a strategy consisting of an understanding of the drivers for environmental compliance or the lack thereof. For the latter, data collection is a critical element and may include data on types of waste generated, volumes, treatment capacity, amounts of waste shipped, historical behaviour, and involved operators, to name a few. Gathering complete data sets aids environmental authorities and law enforcement in defining and assessing the threats and risks of waste crime and designing effective responses.

Box 3.4. Example of an integrated compliance policy (Australian Government)

Australia sets out a range of compliance tools, such as routine monitoring, preliminary enquiries, investigations and enforcement actions, which aim to support regulatory outcomes (Australian Government, Department of Environment and Energy, 2019[41]). The paper targets the regulated community in helping them to understand how compliance encourages, but also how the Department responds to non-compliant behaviour. Compliance activities are risk-based and informed by intelligence. The policy enables a combination of tools, including monitoring, investigations and enforcement action, but also stakeholders' engagements to understand the potential drivers for non-compliance. This policy is an example of combining monitoring and responses to non-compliance by performing investigations and taking enforcement actions.

Case Study – Intelligence and Hazardous Waste Permits

An intelligence review examined the international trends and projections in industries that generate hazardous waste. The intelligence highlighted trends in permit applications and identified some irregularities. The findings of the report helped the Department commence a review of permits, and improved monitoring and stakeholder engagement with the industry.

Challenges in compliance assurance

Despite the progress in developing and introducing waste management laws and policies, countries may still not achieve their key environmental goals without sufficient enforcement of laws. The gap between policy objectives and performance is one of the reasons for this. Below a summary of some of the key challenges contributing to an implementation gap (OECD, 2009[3]).

Legal framework challenges

National legislative frameworks are the primary basis for effective monitoring of waste management operations. Unclear provisions and definitions in legislation can be challenging both to the regulated entities and governments. For example, some goods have been subject to debate as to whether they should be considered as waste or not, and/or to be considered hazardous or not. The classification of waste streams is key to identify which requirements apply for its movement and/or treatment circumstances. The challenge of e-waste classification illustrates this. According to the Basel Convention, used electronic and electrical equipment (EEE) should be considered waste if its holder discards it or intends (or is required) to discard it. Different definitions, or different interpretations, of the definition of waste and of e-waste implemented at the national level may pose challenges in controlling and monitoring the transboundary movements of e-waste. To distinguish whether EEE is a (second-hand) product or a waste, it may be necessary to review all circumstances, including the history of an item, how it is packaged, if it has been tested and the destination of the EEE. Differences in national legislation and interpretation of definitions may lead to diverging decisions from authorities in export, transit and/ import countries (Global E-waste Statistics Partnership, 2020[42]).

Limited resources and weak structures

Cuts in government budgets and often low political support have resulted in limited resources available for compliance checking and enforcement. A study by IMPEL highlights that the lack of proper resources and qualified or specialised staff are some of the main barriers for an effective implementation of environmental challenges (2018[43]).

Lack of data

The recording, collection, storage and analysis of reliable and complete data related to waste management is critical. For example, to identify trends in the waste shipment trade, to detect possible illegal behaviour and to identify threats and risks. Inspection authorities must plan how to use their, often limited, resources in the most efficient manner. To do so, they need to understand the context in which they operate, where and what the highest risks are, and which intervention methods are the most effective. The data gap, caused by lack of data (because it is not reported and/or recorded), lack of exchange of data (within a country but also across countries), or a lack of analytical capacity, hinders proper targeting.

Linked with data are also the performance of threat and risk assessments, which are a valuable tool to aid environmental law enforcement agencies (LEAs) in their efforts. Risk assessments support prioritisation of the workflow of LEAs. They do so by identifying high-risk waste streams, involved (high-risk) stakeholders, routes and modus operandi. The collection of data and analysis of relevant data is a critical part of the risk assessment (Box 3.5). This can for example be data based on:

- Historic behaviour of a specific company
- Import and export declarations submitted to customs authorities
- Notified waste shipments
- Open-source information
- Complaints
- Changes in waste management (for example to introduction of landfill bans or landfill taxes) or changes in import requirements by countries
- Developments in the trade (such as prices for certain materials).

Box 3.5. Findings of the Operational Facility for Fighting Illicit Waste Trafficking (OPFA-Waste) Project

In 2022, research was carried out to collect and analyse data on waste shipments from five pilot countries in the EU (OPFA-Waste Project, 2022[44]), and cross-check this with open source to possibly trigger new investigations (OPFA-Waste Project[45]). The findings showed that the quality of the collected data was insufficient for analytical purposes. Key pieces of information were missing, for example on shipment of non-hazardous waste or the repatriation of illegally shipped waste. Moreover, the way data was collected and stored, would make its proper assessment time-intensive and in some cases even impossible. There were instances where data was collected only in e-mails or in pdf files, or where data was collected at regional level and not made available or shared at the national level.

The research concluded that based on current data collection practices, no proper risks assessment could be delivered to support LEAs in targeting their resources.

Investigations

Investigations into waste crime are time consuming and costly (WasteForce Project, 2020[35]). The collection of evidence is challenging, potentially requiring officials to identify, sample and classify the waste. Often law enforcement agencies do not have the equipment and skills for sampling and analysis. In many cases they need technical support from environmental experts. In the case of illegal trafficking of waste across borders, the involvement of foreign jurisdictions may be necessary. In those cases, the request for information would have to go through mutual legal assistance (MLA) or letters rogatory.

Especially in the era of digital tools, often the question arises how governments store digital evidence and if certain evidence is admissible for court or not. This latter is for example referenced in recent research, which highlights the issue of authenticity of the data (Muhammad, 2021[46]). This research states that earth observation data used in court must be proven authentic (free of manipulation and obtained through a properly working device) and obtained through a proper legal channel.

Rapidly changing waste markets

Waste markets are influenced by new technologies for treatment, insights, policies, import and export restrictions and shipping costs. Response mechanisms to adapt to rapidly changing waste trade are slow (Box 3.6). For example, a strategic analysis by INTERPPOL showed a surge of plastic waste sent to Malaysia from Europe and North America in the wake of China's import restrictions for plastic waste (INTERPOL, 2020[16]). Other recent changes in the plastic waste trade include increased price for shipping (in the second half of 2020 and in 2021) linked to a sudden increase of demand for inter-continental shipping capacity, as well as fewer export destinations due to tightened trade in plastic waste controls (OECD, 2022[47]).

Box 3.6. Recommendation from the EU and Global Impact Analysing Methodology (WasteForce project)

As part of the WasteForce Project (2020[48]), the EU and global impact analysis methodologies were reviewed. The assessment analysed existing methodologies for impact assessment of changes in policies, markets and legislative changes affecting the waste trade and management at EU and global levels, zooming in on the case of plastic waste and e-waste.

One of the recommendations of this work refers to the collection and use of data - on the one hand to have a clear understanding of the waste management market (e.g. which are the problematic waste streams) and what possible consequences may arise as a result of a change in policy (e.g. new routes, new technologies or new infrastructure).

Increased understanding of the market or trade and considering the impact of policy changes, allow agencies to be more proactive in their approach, and not only reactive. This will allow shifting their focus to prevention, rather than taking actions against cases of non-compliance.

4 Digital solutions to support policy responses

The gathering of high-quality data, its assessment and interpretation, is a common challenge across the range of policy responses. Government agencies require improved information and intelligence analysis to better predict impacts of (changing or newly implemented) waste management regulations, identify possible threats, risks and modus operandi, assess illegal actors and activities. More granular and accurate data also enables formulating effective and proportionate responses to breaches of waste management regulations.

This chapter highlights digital solutions that enable collection, management and processing of data and information, as well as creation of knowledge that governments could leverage to strengthen policy responses for strengthened compliance and prevention, detection, and correction of non-compliance with waste related provisions and regulations. It provides an overview of the main digital technologies used for tackling of waste crime, and outlines examples of their implementation in waste management operations across different OECD countries.

Digital technologies in the first instance enable physical objects to sense, record and communicate information about themselves and their surroundings (Ellen MacArthur Foundation, 2016[49]). Additionally, digital technologies such as artificial intelligence (AI) systems can analyse data and predict. Digital technologies have an enormous potential, as they enable and accelerate the analysis of large amounts of data to increase the knowledge bases (Gailhofer, 2021[50]). The ability to deal effectively with large sets of data requires a combination of technologies, first to collect the data, then to store and to analyse and communicate it. For instance, the combination of earth observation (EO) with artificial intelligence (AI) offers more effective, efficient and timely monitoring of environmental impacts and trends, brings new insights in the understanding of driving forces and strengthens predictive capabilities.

The most commonly used technologies relevant for detecting and tackling waste crime include:

- **GPS tracking**: GPS tracking can monitor the movement and disposal of waste, helping to identify illegal dumping and other forms of waste crime. This technology uses the Global Navigation Satellite System (GNSS) network. Using information from the satellites, it enables the tracker to identify its geo-location, which is sent to the user device using the internet.
- **Remote Sensing**: This is the process which uses reflected and emitted radiation to assess the physical characteristics of a certain area. The three main remote sensing platforms are ground based, airborne and satellite. The data collected through remote sensing is in turn processed from energy patterns into images, used for further analysis. Remote sensing may map changes in vegetation, in surface minerals and in surface height due to waste crime.
- **Big data, often integrated with IoT (internet of things), cloud computing and AI systems**: Big data is characterised by the large volume of data, the wide variety of data types and the velocity at which data is generated (from different sources, including IoT). Data needs to be prepared by cleaning and validation and creating helpful datasets (often involving cloud computing). Analysts may then mine data to inform machine learning or predictive modelling. Big data analytics can analyse large volumes of waste data, helping to identify trends, patterns and anomalies that may

indicate waste crime. An AI system is a machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments. Different AI systems vary in their levels of autonomy and adaptiveness after deployment.

- **Geographic Information Systems (GIS)**: GIS can create visual representations of waste, such as data on generation, routing, land use and treatment locations.
- **Online databases and platforms**: Online databases enable collection and verification of data and tracing waste from point of origin to destination.
- **Mobile applications**: waste management authorities, citizens, and businesses can use mobile applications to report waste crime incidents and provide information about illegal dumping sites.
- **Blockchain**: Blockchain technology is emerging as a plausible disruptor of waste management practices. Areas of blockchain use that are beginning to change plastic waste management practices evolved around payment, recycling and reuse rewards, monitoring and tracking of waste, and smart contracts (Steenmans, 2021[51]). Only in a few cases have public bodies apply blockchain technology related to waste management or monitoring (Blockwaste Project, 2021[52]).

The following sections present and discuss experiences and examples of the current application of digital technologies in monitoring waste management and tackling waste crime by OECD member country governments.

Online platforms and machine learning help increasing transparency and enhancing compliance promotion

One of the key approaches to promote compliance is through enhancing transparency and public access to information on the level of compliance by waste operators. Digital technologies not only support and improve the collection of data, including on amounts of waste generated, transported and disposed, they also enable easier accessibility to this information. An example is the use of online data dashboard interfaces as tools to visualise, analyse and display data. In practice, online platforms and machine learning solutions have helped improve transparency in compliance and enforcement.

The United States Environmental Protection Agency (US EPA) has developed a transparency portal called Enforcement and Compliance History Online (ECHO) (US EPA, n.d.[53]). This **website provides integrated compliance and enforcement information** about regulated facilities nationwide. It offers the opportunity for individuals to search for non-confidential data on facilities, permit data, investigate pollution sources, search for enforcement cases and analyse trends in compliance and enforcement data. It also offers the option for citizens or whistle-blowers to report a violation anonymously. Regulators can access more data and additional visualisation options in the portal through a login.

Another application supporting the prevention of illegal waste management operations is the **predictive model for end-of-life vessels**, developed by the Netherlands Inspectorate for Human Environment and Transport (ILT). The predictive model is based on machine learning and focuses on the problem of ‘beaching,’ or intentionally grounding, of end-of-life vessels for dismantling. This phenomenon is driven by factors such as the price of steel scrap and unclear legislation or legal gaps. The model, fed by different open and closed sources, identifies, based on parameters like age of the vessel and oil prices in case of bore platforms, which vessels owners are likely to soon scrap. Based on the information provided by the model, the ILT establishes meetings with the involved shipowners to make them aware of the applicable rules and procedures for the scrapping of their vessels. Until now, the model was correct in 75% of the cases in predicting the vessels that owners were soon to scrap. In 90% of those cases the prediction of the vessel being beached in contravention of the regulations was correct. The predictive model is not a decision-making tool, but rather a source of advice and guidance for the inspectors.

Cradle-to-grave databases, GPS tracking devices and forensic data collection tools improve traceability and facilitate compliance monitoring

The use of digital technologies for compliance monitoring purposes is more widespread than for compliance promotion. Digital solutions typically leverage the (combinatory) power of online platforms, big data, data based on algorithms or machine learning models, and tracking devices using GPS signals. They facilitate a better use of data for compliance monitoring, by combining different sets and sources of data, including the ability to trace waste from point of origin to destination and the option to verify and crosscheck data on waste shipments and balances, as well as identify sites and facilities with greater likelihood of violations.

The Canadian Notification and Movement Tracking System (CNMTS) is a secure online platform implemented by Environment and Climate Change Canada (ECCC). The **system is set up to issue permits and monitor operations associated with transboundary movement of hazardous waste and hazardous recyclable material**. The system allows operators to submit notifications and obtain official permits, as well as to generate and track movement documents, respectively divided in a permit module and a movement module. The permit module is linked to the movement module. The system flags discrepancies between the permits and the actual shipments. The movement modules allow tracking information regarding importers, exporters, importing facilities, exporting facilities, carriers, wastes details, transit countries etc. The system was implemented in the 1990's and has since been further developed into an online interface with a switched data entry from the government to the user/applicant. As a result, the issuance of permits has significantly improved overtime, both in terms of time and of quality data input. Additionally, the ECCC is working on linking CNMTS database with the declarations submitted to Canada Border Services Agency (CBSA) and improving the quantity and quality of the data they get from CBSA. This allows for cross-checking of data and to carry out data and trend analysis, based on Customs declarations and ECCC information.

In the United States, information about hazardous waste is submitted and stored in the Resource Conservation and Recovery Act Information (RCRAInfo). RCRAInfo can **track hazardous waste from cradle-to-grave**, by collecting information from domestic point of generation or import into the U.S. through transport to domestic disposition or export for foreign disposition. The data in the system is organised in different modules such as the biennial report module, the compliance monitoring and enforcement module, the handler module, the permitting module, the financial assurance module, the corrective action module, and e-Manifest module, as well as the Waste Import Export Tracking System (WIETS) module. The data in RCRAInfo is accessible via various (public and closed) search interfaces, and through a dashboard which allows data visualisation. The key identifier is the handler number, which can be obtained by operators when they register in the handler module. The system self-validates the data by performing cross-checks. Cross-checks for exports of waste are carried out between US Customs and US EPA based on consent numbers and associated reference data. Overall, this technology has helped in increasing traceability by providing access to higher quality and more readily available information.

The North American Notice and Consent Electronic Data Exchange (NCEDE) system connects the respective environmental authorities of Canada, Mexico, and the United States, and allows for the sharing and transacting of notifications and consents online between the national systems for processing and communication. Specifically, NCEDE is connected to the US EPA's WIETS module under US EPA's RCRAInfo, to ECCC's CNMTS, and to the Mexican Ministry of Environment and Natural Resources' (SEMARNAT's) Intercambio Electrónico de Datos de Notificación y Consentimiento (IEDC). The most current version of NCEDE has significantly improved the efficiency of communication of notices and consents between the three countries by establishing US-Mexico and US-Canada API based exchanges using JavaScript Object Notation (JSON). Overall, the NCEDE has resulted in increased protection of the North American environment through improving the efficiency of the prior informed consent process and providing higher quality data for compliance analysis.

Austria operates an Electronic Data Management - Environment system (EDM). A large number of **legal obligations for domestic and foreign waste companies are handled through this electronic waste data management** system, such as annual waste balances, electronic notification applications, transport announcements, and receipt and processing confirmations for notifications. The EDM system provides 23 specialised applications, including e-Shipment ("notification database" for waste shipments), e-balances (annual waste balances), e-Consignment Note (for hazardous waste and POP- waste), e-WEEE, e-EOL-vehicles, e-Batteries, e-Composting, to name a few. This system allows enforcement users access to a myriad of useful data to combat illegal waste shipments: i) read access to the general master data of all waste producers, waste collectors and waste handlers as well as waste carriers (names, addresses, contact data, locations, authorisations of waste collectors/handlers); ii) authorisations of waste collectors and waste handlers (scope of authorisation with indication of the Austrian key numbers for waste and their description, and indication whether the company treats or only collects waste or is allowed to do both); iii) information on legal framework and lists of wastes; and iv) read-only access to notifications in the EDM-application e-Shipment (e.g. search for notification number, notifier, consignee, waste type, key number (EWC or national code), R/D operation, waste carriers, registration report of the shipment 3 days prior to the actual shipment, confirmation of the consignee on receipt of the waste, confirmation of the consignee on disposal or recovery of the waste is possible). By entering a specific notification number, environmental inspectorates, police and customs can access detailed information on the notification (e.g. duration of consent, details on origin of the waste) and check whether the consents of all competent authorities concerned have been obtained. Easier access to data made the processes more time-efficient and enabled waste controls at all stages in the management chain.

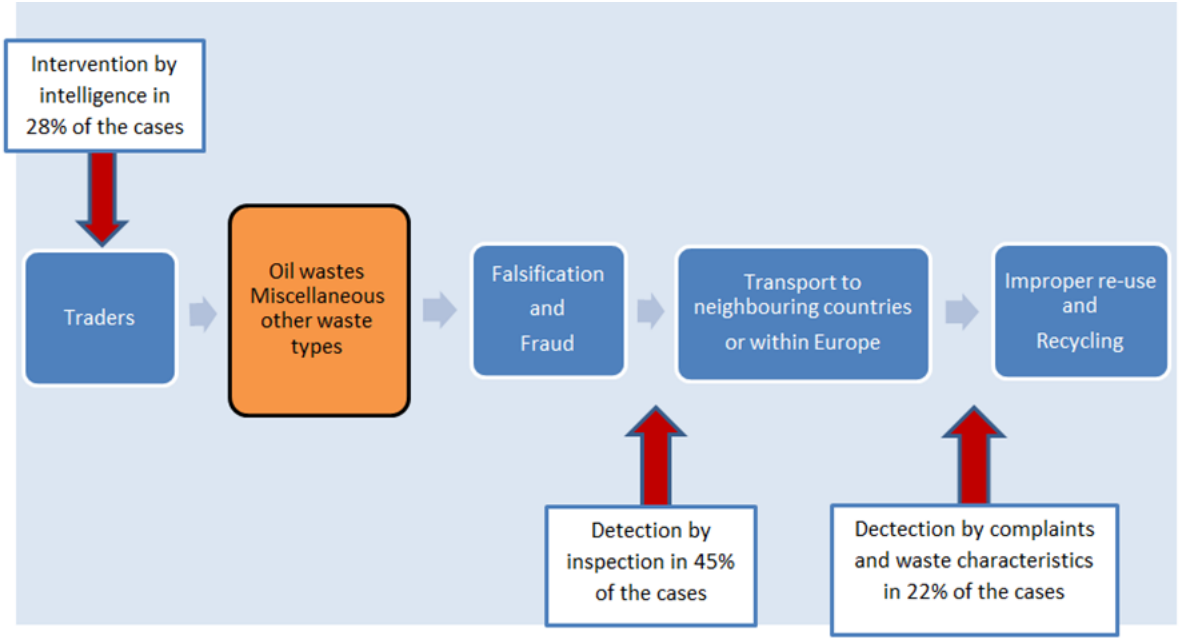
A different technology, based on GPS tracking devices, was developed within the e-Trash Transparency Project by a non-governmental organisation (NGO) - the Basel Action Network (Basel Action Network, n.d.[54]). In a series of batches, more than 400 **GPS trackers were applied to pieces of discarded equipment**, such as LCD monitors, desktop computers and printing devices. It enabled following the shipment of e-waste originating in the United States, Canada, Australia and the EU, and its final destination. The trackers used global cellular phone systems, which have a GPS reader and can send text messages. The attached battery had lifespan of one year or more. The trackers could be programmed remotely to connect with a certain frequency to satellites to determine the location, or alternatively they would connect to cell towers with an accuracy of 20km. The data collected by the tracking devices showed that in a number of instances e-waste was exported outside of countries (ranging from 6% in the EU to 40% in the United States), and in some cases even to countries where an export ban applied, or a prior notification procedure was required. In the case of the EU trackers, more than half of the exports, ended up in developing countries, like Nigeria, Ghana, Pakistan and Thailand. These could be identified as illegal trafficking, depending on the actual waste classification and destined use in the country of destination. In a few instances the final destination of e-waste was very likely a solid waste landfill. Under the LIFE SWEAP project, in part funded by the European Commission, the use of GPS trackers is currently tested as part of tracking operations (SWEAP, n.d.[34]). However, preliminary results show that the use of tracking devices may constitute 'directed surveillance,' on the basis that the devices and technologies are being deployed for crime detection. Legal clarity on their uses and how to deal with personal privacy still requires further review.

The Forensic Big Data Analysis (FBDA) of the Netherlands Forensic Institute (NFI) developed a prototype of a **forensic tool for data collection, retrieval, and analysis for illegal waste trafficking**. FBDA core activities include text mining, data profiling, financial data analysis and social network analysis. It aims to improve access to historical data which was generated from previous cases related to waste trafficking, which in turn can be used to develop patterns that can help identifying future cases of waste trafficking. The data generated by forensic research contains information about vulnerability of specific waste streams for criminal activities, how it occurs, and how this can be detected. The overall outcomes of the forensic data analysis case study on illegal waste trafficking are summarised on headlines in Figure 4.1. In total 2 150 cases were selected from the NFI database and after a refinement step, 44 cases were analysed in

detail focusing on types of waste involved in the case, illegal activities, waste movements type of suspects (companies), trigger for the investigation and the results forensics. The results of gathering intelligence on waste traders show that in 28% of the cases interventions could have been taken and that inspections revealed 45% of the cases of illegal trafficking. For now, the information in the Environmental Forensics Database is limited to the cases which occurred in the Netherlands. Linking the database with other information sources in the future might make the prototype suitable for international uses (WasteForce Project, 2020[55]). A digital solution making **predictions about future outcomes using historical enforcement data** has also been developed as part of the RCRAInfo system in the US. This module uses predictive analytics from machine learning models, to identify which sites and facilities to inspect. Parameters include the likelihood of violations based on historical enforcement data, and the identification of high-risk facilities based on the amount and type of waste generated. Since using this prediction module, the success rate of inspections has increased by 47%.

The application **of Risk Management approaches by Customs Administrations** to target possible suspicious shipments. Digitalisation is a key to create a paperless customs environment for facilitation of Customs processes: electronic clearance of goods, single window concept, non-intrusive inspections and risk management based on data analysis are pillars for modern Customs administration (World Customs Organization, n.d.[56]) . Customs may obtain digital data of cross-border goods, exchange electronic data, which is normally timelier than paper-based information, with relevant government agencies as well as with other Customs administrations abroad. Enhancement of use of data for risk management purposes order to move towards the digital future of Customs administrations. Customs administrations can no longer interact a physical manner with 100% of cross-border flows. By exploiting a substantial amount of data at their disposal, using predictive analysis and machine learning, Customs enable smarter control of Customs risks and allow Customs administrations achieving their objectives. In order to develop risk profiles for waste trade, risk indicators need to be identified. These can be based for example on Harmonized System (HS) codes, the value of the trade or import and involved operators.

Figure 4.1. Key finding forensic data analysis for illegal waste trafficking



Source: WasteForce Project (Marion Stelling, 2020[57]).

Remote sensing and drones equipped with lasers have potential to ensure intelligence-led investigations and prosecution of waste crime

Government use some digital technologies to investigate waste crime or breaches of waste management provisions. However, some of these overlap with technologies used for monitoring purposes, since often findings from inspections are a starting point to trigger investigations. Data generated through various earth observation methods in combination with machine learning represent an effective and cost-efficient method for monitoring environmental contamination and detecting illegal waste disposal sites. In certain instances, images from observations are permitted as evidence to court and may be used by the prosecution in establishing the level of penalties.

Remote sensing (RS) technology offers the possibility to go back in time and assess the time-lapse of the possible offence. The option of using RS techniques to detect waste crime, has been assessed by the LIFE SMART Waste Project (Scottish Environment Protection Agency, 2020[58]). The project investigated the technical capabilities, regulatory requirements, and opportunities for innovative ways of understanding, tackling and reducing waste-related crime. It concluded that data created with RS, should be considered a key component of intelligence-led and better-informed enforcement. Especially its ability to provide information and evidence from a historical perspective, which could contribute to the monitoring programme and investigation. So far, the experience of using RS data in the waste crime sector has shown that key indicators to suspected illegal sites relate to mapping vegetation and vegetation change, changes in surface minerals and in surface height. A variety of sensors are used to achieve high-precision observations, including infrared sensors (the effectiveness of which is limited by the presence of cloud cover, which hinders the collection of data at certain wavelengths for surfaces beneath the clouds) and radar sensors (which transmit electromagnetic waves and an penetrate clouds and fog without being affected by light) (Remote Sensing, 2023[59]). Research by Glanville on sensor requirements to support the mapping of illegal domestic waste disposal sites in Australia concluded that the literature on the use of remotely sensed data and data analysis techniques to detect and monitor illegal waste disposal sites is lacking and further opportunities to develop this technology should be encouraged (2015[60]).

The German federal police and coastguard use these technologies to assist in shipbreaking investigations. The focus is on tracking and tracing ships that have been shipped to recycling facilities and dismantled in contravention with EU legislation. These cases often start with a tip-off, but concern cases that happened in the past. Once a ship has been identified, **satellite images** (generated through the Copernicus Earth Observation programme (European Commission, n.d.[61])) are used to follow the route and map the stops of the ship before it was beached. When combined with open-source information, satellite images permitted the investigation of 60 cases, since the police started using this tool. In 90% of those cases, the police were able to track the ship and its origins. Moreover, the satellite images are permitted as evidence to trigger the initiation of an investigation, and to be submitted as evidence to court.

Thermal patterns (a dataset of infrared images connected with typical environmental phenomena) and thermal tracking approaches can identify environmental contamination based on a mix of **aerial infrared thermography with a thermal patterns database** (Lega, 2014[62]). The methodology discussed in the paper argues that starting from the environmental damage point, it should be possible to search the cause and define the source-path-target model. The paper demonstrates the added value of the use of an integrated approach that combines aerial platforms (e.g. drones), advanced sensors (e.g. infrared radiation (IR) cameras) and specific IT tools (e.g. multi-view 3D reconstruction and edges detection) in environmental police investigations, for example to detect illegal landfills.

In France, **drones with laser technology evaluate the volumes of illegal waste dumps**, to calculate the costs for clean-up and the profits made by disposing of waste illegally. Prosecuting authorities can use this information in formulating their demands or proposed level of fines or penalties. Another case where enforcement has used drones and cameras, was when a site had to be accessed real-time, but the

circumstances were not safe for the owner of the waste site to physically join the event. By following the investigation on the spot via cameras and images generated by drones, the court agreed that the requirements to have the owner on the site were met.

The French authorities also witnessed of 20% increase in the detection rate of illegal waste sites **applying machine learning algorithms to satellite imagery**. Similar technologies have been tested in research on deep-learning based dumpsite detection from satellite imagery (Sun et al., 2023[63]) This paper argues that it is almost impossible to locate dumpsites on a global scale using manual methods and that satellite imaging technology has become a powerful basis for earth observation. By applying deep learning methodologies (i.e. a subset of machine learning that uses artificial neural networks to mimic the learning process of the human brain) and applying new deep convolutional networks to high-resolution satellite images, this approach can provide an effective, efficient, and low-cost method to detect dumpsites. In sampled areas of 28 cities around the world, the model detected nearly 1 000 dumpsites that appeared around 2021. This approach reduces the investigation time by more than 96.8% compared with the manual method.

The United States approved the use of surface emission monitoring of landfills by unmanned aerial systems starting in 2022. When evaluating the method, the unmanned aerial system detected 287 possible instances of exceeding surface emission standards, more than double the existing compliance reporting method at the same sites (U.S. EPA, 2022[64]).

Connecting digital tools can facilitate application of artificial intelligence (AI) systems, but this potential is presently underutilised

The OECD has previously noted that other digital technologies can help facilitate and amplify AI systems' operability and learning (Barteková and Börkey, 2022[7]). An AI system is a machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments (OECD, 2023[65]). Deep learning involves training artificial neural networks to recognize patterns and make decisions based on input data (Europol, 2023[66]).

There have been rapid advancements in the capacity of AI and in particular generative artificial intelligence (GAI) in recent years. GAI generates new content such as text, image, audio based on training examples and prompts (Lorenz, Perset and Berryhill, 2023[67]). One now common form of GAI can generate responses in natural language (generative pre-trained transformers [GPT]) (Jovanovic and Campbell, 2022[68]; OECD, 2023[69]). GPTs are foundational models that can generate media beyond simply natural language.

The literature review and interviews with law enforcement officials in OECD member countries has indicated that recent efforts have been primarily focused on digitalisation of data and records. This effort is helping to create a sufficient mass of digital data that could be used in the future to train AI tools. These in turn could leverage predictive analytics, integrating deep learning to improve satellite imagining, and inform compliance monitoring and responses to non-compliance. Whilst the integration and connection of various digital tools is a gap, the full potential of digitalisation remains underutilised. OECD member countries have recently developed and implemented early applications of AI systems (Box 4.1).

Box 4.1. Early examples of the application of AI systems to promote compliance with waste law

The United States and the Netherlands have each started to use AI systems to predict the likelihood of non-compliance with waste law. The Netherlands used an AI system to predict when cars would likely be shipped to African destinations in violation of these countries import restrictions. Similarly, the Netherlands has used an AI system to predict the end of life of shipping vessels. In both cases the systems help inform outreach to promote compliance. The United States has developed an AI system to identify high-risk facilities for inspection. These systems help governments to apply limited outreach and enforcement resources more efficiently.

GAI could also serve to improve compliance promotion with waste laws. For example, AI-enable chatbots could engage with the public as a first stop for answering routine questions of compliance and law interpretation.

There is enormous potential for AI to increase compliance, monitoring of compliance, and response to non-compliance. It can help to leverage capacities and direct the use of limited resources to target governments' effort more efficiently.

Significant challenges to the application of AI, and in particular GAI exist. Large language models have demonstrated difficulty in coherently explaining its mechanisms for complex decision-making (Lorenz, Perset and Berryhill, 2023[67]). There are also concerns regarding fairness and ethics as these machines can perpetuate existing patterns (Jovanovic and Campbell, 2022[68]). The G7 noted that GAI could exacerbate misinformation, infringe intellectual property rights, and enable privacy breaches (OECD, 2023[70]) Applied to criminal detection, there is concern that AI could facilitate targeting of specific groups. The OECD adopted AI principles in 2019 which have helped inform member countries' development and implementation of 50 national strategic and government wide initiatives to steer trustworthy use of AI systems (OECD, 2023[71]). Finally, AI tools are dependent on the availability of data. For example, ChatGPT was trained with 45 terabytes of data (McKinsey & Company, 2023[72]). However, there is to date a much more limited body of data from which to draw upon for non-compliance with waste law.

There is also a risk that GAI may help to inform criminal activity. For example, Europol workshops related to law enforcement and the use of chatbot AI systems identified a risk that models could provide specific steps to enable various types of crime. Fraud and impersonation are crimes of particular concern (Europol, 2023[66]). This could become a risk for waste crime, which is often associated with fraudulent crimes, such as money laundering.

Limitations to using digital technologies for improved environmental compliance

By developing and applying digital technologies for environmental compliance purposes, governments also face a number of limitations to these technologies. These can be categorised into *legal*, *technical* and *financial* obstacles.

Legal obstacles relate to lack of legal clarity on how, by whom and under what conditions certain technologies can be used. This is especially true for tracking devices. Further, the admissibility of the evidence gathered with or by digital technologies may be questionable in court. The use of technologies should be in line with privacy and personal data protection requirements. However, there are remaining legal questions surrounding the use of digital technologies, particularly concerning privacy. For example, drones can capture images and collect data implicating waste crime, but the collection of such data as evidence may be subject to questions of admissibility The pace of technological development and diffusion can outpace regulation creating additional legal questions for interpretation.

Limitations are also present due to *technical issues*. These can relate to capacity issues if lacking skilled staff to operate technologies, for example in the case of drones, or to develop scripts and algorithms to 'teach' computer systems how to recognise patters that may indicate waste crime (such as illegal waste sites). The technologies themselves have limitations too, for example the lifetime of a battery of a GPS tracker. Additionally, coordination of existing governmental systems to 'talk to each other' (i.e. interoperability) and exchange of data between agencies nationally and internationally remains an obstacle for a more effective and wide-spread use of digital technologies (as mentioned with the various online databases and platforms).

Digital technologies may also represent a *financial burden* to governments. The development of software or the purchase of high-resolution satellite images or sensors, as well as subscriptions to certain tools (such as trade databases) can pose a financial burden to governments. Governments may incur additional costs through resource consumption. For instance, blockchain energy consumption by public blockchain-based systems can be costly (Georg Eder, 2019[73]). However, the burden could be offset by the accrual benefits such as cost saving and more efficient use of limited resources.

5 Policy implications for the use of digital technologies in better enforcement of waste regulation and elimination of waste crime

The use of digital technologies can help to improve compliance with waste management laws and the detection of violations. As discussed in the previous chapter, a wide range of technologies are being developed and tested by OECD member countries. Initial results demonstrate that applying digital solutions in enforcement of waste regulation and elimination of waste crime helps to increase the rate of non-compliance detection and improves targeting. Together, this means that digital technologies are making compliance promotion, monitoring, and response efforts more effective and cost efficient.

To date, the efforts of digitalisation focused predominantly on the digitalisation of data rather than on its transformation and use for intelligence-led enforcement actions. Digital technologies have allowed for closing the data gap by enabling reporting and recording of data by different actors all along the value chains. Nonetheless, major gaps in exchange of data (across national authorities, between different levels of government, and internationally) prevail, while experience with using data for analytical purposes is rather sparse. The full potential of digitalisation remains underutilised because governments have yet to widely and effectively apply digital solutions for targeting and enforcement purposes.

The collection, quality and availability of data and the linking of data needs to improve. More accurate and real-time data is critical to improved waste management practices, its verification and tracing. In order to ensure a plurality of data, this needs to be collected from a range of relevant sources, including open-source information, import and export declarations submitted to customs authorities, notifications of waste shipments to environment inspectorates, as well as changes in trade patterns (such as evolution of prices for materials and restrictions in import requirements) and historic behaviour of companies. The data should be recorded and stored in databases which are interlinked and interoperable, and which are made widely available for public uses. Publicly available information can also help waste management operators and handlers to more easily identify the requirements for movement and treatment of different waste streams across different constituencies and facilitate citizen monitoring and reporting of violations. OECD country governments are developing systems towards this aim, but these efforts are largely ongoing and at an initial phase.

In a second phase of digitalisation, once processes are in place to collect and store relevant data digitally, efforts should focus on expanding the use of this data for improved risk assessment. Countries are encouraged to continue with exploring new uses of existing digital technologies, seeking inspiration from their application in other sectors. This may include wider adoption of tools leveraging predictive analytics, integrating deep learning to improve satellite imagining, and exploring applications and understanding benefits of blockchain technology for innovative ways of data collection and for improved tracking along the value chains.

Digital technologies should be more widely applied to inform the design of policies for better waste management and environmental compliance. By helping to identify key trends in transboundary movements of waste and in domestic waste offences, digital technologies, and the data they help generate, can provide policy makers with a comprehensive picture of waste generation and disposal trends, support more effective regulation of waste and facilitate the transition towards a circular economy.

Digital technologies should also be further developed and applied to improve enforcement responses to waste crime. Digital solutions can support more effective and cost-efficient compliance monitoring, help detect possible illegal behaviour and identify current and future threats and risks. This is especially important given the limited budgetary resources for these efforts. Digitalisation can not only contribute to better compliance promotion, but it also allows better targeting of possible suspicious activities (through improved understanding of high-risk waste streams and of intervention methods that are the most effective), helps generating evidence for enforcement actions and better informing prosecution. To streamline the enforcement efforts enabled by digitalisation, and to overcome current legal obstacles, countries should consider developing frameworks to identify criteria for the application of these technologies and coordinate internationally.

Digital solutions are applied within a larger governance structure that aims to promote, monitor and enforce compliance with waste regulation. The digital transformation can help to change social and economic drivers of waste crime, but digital solutions alone are not sufficient to ensure compliance. *Policy responses beyond those enabled by digital technologies will therefore also be necessary.* These may include clear definition of waste laws and requirements, improving enforcement through higher sanctions and prosecution rates, as well as defining traceability standards and cooperation between relevant government bodies.

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