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## Review Article

## Trends in counterfeit drugs and pharmaceuticals before and during COVID-19 pandemic

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## ABSTRACT

Counterfeit, fake, adulterated or falsified drugs and pharmaceuticals, could be branded or generic drugs, excipients and active substances (in drugs and vaccines), medical supplies and devices, etc, intended to pass as the original. Counterfeits are always inferior in terms of quality, safety and efficacy compared to the original pharmaceuticals, and subsequently, they pose an unpredictable risk to public health and lead to loss of confidence in medicines, healthcare providers, and health systems. In the decades before the outbreak of the COVID-19 pandemic, a constant trend of increased trafficking was reported. However, the pandemic created a combination of public health emergency, economic distress, and misinformation-driven panic that made problematic the access and supply of high quality essential medicines and health products, and pushed consumers and vendors even more towards counterfeit pharmaceuticals. This contribution aims to review the trends in counterfeit drugs and pharmaceuticals trafficking, the health impact of their use, as well as, measures and actions implemented to restrict their proliferation, before and during COVID-19 pandemic; the relative recommendations, the expressed perspectives and the existing limitations are thoroughly discussed.

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## 1. Introduction

Counterfeit, fake, adulterated or falsified drugs and pharmaceuticals, could be branded or generic drugs, excipients and active

substances (in drugs and vaccines), medical supplies, personal protective equipment (PPE), medical devices (including parts and accessories), intended to pass as the original [1]. The World Health Organization (WHO) is using the following three terms for categorizing them: (a) "falsified": they are products that fraudulently misrepresent their identity (e.g. name), composition (mislabeling of content), or source (e.g. country of origin or authorizing organization). Could be perfect imitation of the original pharmaceutical (same packaging, same active ingredients at the right concentration) or in lower/higher quantities than indicated on the label or with

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different ingredients or with no active ingredients at all. They could also be the result of repackaging of unapproved drugs to resemble approved ones or could be the result of theft and resale of approved drugs, (b) “substandard” (also called “out of specification”): they are products that have been authorized but fail to meet their quality standards and/or specifications. Could be the result of improper manufacture or storage or products that have expired (deteriorated authentic pharmaceuticals), and (c) “unregistered/unlicensed”: they are products that have not undergone evaluation and/or approval [2–4].

Counterfeits are always inferior in terms of quality, safety and efficacy compared to original pharmaceuticals; they pose an unacceptable risk to public health and lead to loss of confidence in medicines, healthcare providers, and health systems [3,5,6]. In the past decades (before the outbreak of the COVID-19 pandemic) a constant trend of increased trafficking was reported [3,7]. The pandemic though has reshaped the demand for goods and services worldwide exposing even more the vulnerabilities of the global health care systems [8]. The combination of a public health emergency, economic distress, and misinformation-driven panic has caused problems related to access and supply of high quality essential medicines and health products, leading to drug shortages, quality issues, uncertainty, and price volatility [8–10]. This situation has pushed consumers and vendors even more towards counterfeit pharmaceuticals.

This contribution aims to review the trends in counterfeit drugs and pharmaceuticals trafficking, as well as, the health impact of their use before and during COVID-19 pandemic; the relative recommendations, the expressed perspectives and the existing limitations are thoroughly discussed.

## 2. Origin and dissemination

According to the 2020 Organization for Economic Co-operation and Development (OECD) report the primary countries from which adulterated pharmaceuticals originate are considered to be China, Hong Kong, Singapore and India [11]. While China and India are the main producers, the United Arab Emirates, Singapore, Hong Kong, Yemen and Iran are serving as transit economies mainly exporting to the United States, Europe, Japan, some South American economies and Africa [11].

Globally, the market is estimated to be worth between USD 65 and 200 billion dollars each year, making it a very lucrative criminal enterprise [12]. While the range of affected medicines is growing and evolving, the prime targets in developed countries are life-style expensive pharmaceuticals like hormones, steroids, anorectics, erectile dysfunction drugs and psychotropic drugs, while in developing countries life-saving medicines like antibiotics, anti-malarials, anti-tuberculosis drugs and antiretroviral drugs [3,11]. Other pharmaceuticals targeted by counterfeiters are diabetes treatments, HIV/AIDS and cancer treatments, pain killers, central nervous systems medicines, lipid-lowering drugs, and medications for treating depression and blood pressure [5,11]. Most of them are distributed via e-commerce and social media platforms, rogue pharmacies, messaging applications and the dark web while express courier and postal parcels are the most popular ways of shipping [11,13].

Main reasons for the prevalence of counterfeit products throughout the world are (a) high demand for less expensive drugs, (b) low availability of medical products, (c) social tolerance for counterfeit products, (d) globalization and consumer access to the internet (e-commerce), (e) complex and fragile supply chains, (f) limited technical capacity to monitor products throughout the supply chain, (g) complex import-export mechanisms, (h) the use of free and special economic and trade zones, (i) lack of law enforcement, (g) weak national regulatory policies on the manufacturing and marketing of medications, and (k) lack of adequate financial and

political commitments [3–5,11,14–19]. For these reasons the penetration of counterfeit products is generally higher in developing countries with West Africa and South America being reported as the areas mostly affected [11,20,21]. In 2017, the WHO after reviewing laboratory results on medical products from 75 low- and middle-income countries (LMIC), reported that 33.6 % of hypertension, cancer, epilepsy, analgesic uterotonics and immunosuppressants drugs, 11.8 % of antimalarial drugs, 7.2 % of antibiotics and anti-infective products, 6.7 % of tuberculosis medicines, and 4.2 % of HIV medicines were falsified or substandard, while approximately 10.5 % of all pharmaceuticals may be falsified in those countries [20].

In high-income countries only 1 % of the drugs in the legitimate drug supply chain are counterfeit. However, this figure is derived from only a small sample [20,22]. The Pharmaceutical Security Institute's data on counterfeiting, illegal diversion and theft incidents from 2016 to 2020 show that there has been a rise in the number of discovered incidents from 3146 in 2016 to 5081 in 2019, and a decrease in 2020 to 4344 attributed to the coronavirus pandemic [23]. Most of these incidents (1579) occurred in North America followed by Asia Pacific with 1151 incidents [23]. This indicates that the problem in developed countries may have been underestimated. However, high-income countries have a strict regulatory framework, technological means, and financial resources to detect and limit the distribution of fake drugs and pharmaceuticals [15].

The act of falsifying a medical product is a criminal act that constitutes not only consumer fraud but a threat to public health and safety [16]. Illicit trafficking of counterfeits is an attractive money-making venture to criminal groups compared to other criminal activities, due to the combination of high profit, low risk of detection and prosecution, low penalties, and the ease with which consumers can be deceived [7,11,24]. Since the outbreak of the COVID-19 pandemic, the threat posed by fake medicines and medical products has increased dramatically. While this pandemic was expected to have a negative impact on the global operations of transnational organized criminal groups, these groups quickly adapted [24]. They took advantage of the high market demand for medicines, personal protective equipment (PPE) and hygiene products and made lucrative profits from the sale of counterfeit items [13]. One example is chloroquine, as consumer demand for this product increased during the pandemic, criminal groups flooded the market with counterfeit, unauthorized or diverted medicines [13]. Moreover, criminal networks carried out prescription fraud using fake paperwork to obtain chloroquine and other medicines under study as potential treatments for coronavirus [13]. For all the above the WHO issued a Medical Product Alert No 4/2020 for falsified chloroquine [25] and Medical Product Alert No 3/2020 for falsified COVID-19 medical products [26] requiring vigilance from all countries on fake products that claim to prevent and cure COVID-19.

## 3. Health impact and consequences

Counterfeit drugs and pharmaceuticals are a major issue affecting public health, and healthcare systems around the globe. They may cause life-threatening implications and adverse effects to patients (who are very often unaware of the issue), increased risk of prolonged illness, failure of treatments or cure, and/or mortality [4,11,27]. In the United Kingdom almost 32 % of those who have bought one or more counterfeit medicines have suffered a health issue as a result [28]. Considering that in Africa almost 60 % of the medications are substandard one can imagine the magnitude of the consequences [15,29]. In China it was reported in a newspaper that almost 192,000 of its citizens died as a result of counterfeit medications [30], while WHO estimates 72,430 and 116,000 additional deaths occur annually from the use of counterfeit drugs for pneumonia and malaria, respectively [20]. Probably the numbers are even

worse as many of such cases go undetected in developing as well as developed countries even today.

The problem was first recorded long ago, with periodical crises in the supply of antimicrobials, such as fake cinchona bark in the 1600s and fake quinine in the 1800s [31]. Since then numerous cases have been documented in which patients have suffered harm or died due to the use of adulterated medicines. Severe hypoglycemia has been documented in Singapore in 2008 which was associated with contamination of illegal sexual-enhancement drugs with glyburide [32]. The consumption of counterfeit cancer-fighting medications, that in some cases included no active ingredients, has been reported [33], as well as the consumption of a counterfeit diet pill that was actually a pesticide with lethal consequences [34]. Heparin products were substituted with a cheaper counterfeit substance and were inserted into the supply chain causing the death of 81 people in the United States due to adverse effects [35]. The deaths of 89 children in Haiti and 30 infants in India occurred after the consumption of paracetamol cough syrup which was prepared with diethylene glycol a toxic chemical used in antifreeze [36]. The deaths of 2500 Nigerians were attributed to the use of vaccines that were found to lack any active ingredient [36].

Fake drugs could also have a consequential cost to public health sometimes with fatal outcome. For instance, counterfeit anti-malarials, antibiotics, and antivirals could contribute to the progression of microbial resistance and drug-resistant infections [11,15]. When treating pneumonia and inadequate quality of levofloxacin is used, the minimum required inhibitory concentration may not be achieved, thus leading to resistance and treatment failure [15,37]. Long ago a phenomenon of resistance of malaria parasite species to antimalarial drugs was observed in Cameroon that was linked to falsified chloroquine tablets [9,38]. In recent years, HIV drug resistance is being observed in developing countries mainly due to poor quality of the antivirals used [39]. Moreover, risk factors such as blood pressure, serum glucose, or serum lipids that are not being adequately controlled by using ineffective counterfeit drugs, could also lead to major health risks [22].

A big challenge in environmental terms is the pollution from pharmaceuticals which in case of counterfeit medicines turns to be even more serious as their actual composition (active ingredients and excipients) may often be unknown. Another aspect of this issue is the environmental pollution from dirty practices by an unregulated criminal activity involving potentially toxic chemicals [11].

Last but not least, the economic costs of treating patients who have suffered adverse health consequences after the consumption of adulterated drugs should also be evaluated. Moreover, patients and households lose income due to prolonged illness or death, legitimate producers lose sales to counterfeiters, while governments lose taxes and face long term issues related to managing health care systems. All the above have a domino effect on health care systems and the wider economy [11].

#### 4. The impact of COVID-19 pandemic in counterfeit dissemination

Since the outbreak of the coronavirus pandemic the world is facing many challenges. Many problems have arisen regarding demand and supply of high quality essential medicines and health products and the sale of falsified health products has increased [40,41]. Moreover, dark web marketplaces and commercial websites accessible via free software, have gained significant popularity for buying fake drugs and medical products [8]. From the first months of the pandemic falsifiers adapted fast to the new situation [9]. The most counterfeited products related to COVID-19 have been antiviral medications, antimalarial chloroquine, vitamin C, painkillers, antibiotics, and herbal medicines and medical supplies like face masks, coronavirus testing kits, gloves, ventilators, disinfectants, gels, soaps

and cleaning wipes [13,17]. Moreover, fake coronavirus vaccines were reported to be sold in certain parts of the world [8,42].

The pandemic caused a public health crisis that stressed nearly all health care resources to their breaking point. Shortages in drug supply emerged as the need to treat patients with COVID-19 outstripped the supply of sedatives, analgesics, and antiviral products (hydroxychloroquine, remdesivir) leaving patients scrambling to find medication like hydroxychloroquine to control arthritis or lupus even in countries like the United States [43]. The supply chain disruption was also caused by the reduced production and export of some medicines, active pharmaceutical ingredients and raw materials owing to the closure of countries and borders [44]. For example, in the U.S.A. 70% of manufacturing sites that make active ingredients for medicines are overseas, with almost one-third of them in China and India, while most medical products used in Africa are imported mainly from China and India, as well. Their dependence from other countries led to shortage of medical supplies during the outbreak [10,12].

Although challenges, ranging from weak regulatory and legal frameworks to the prevention of the manufacturing and trafficking of counterfeit health products and cyber security shortcomings, were evident before COVID-19, the pandemic has exacerbated them and it will be difficult to make significant improvements in the immediate future [28]. Taking into account that less than 30% of medicines regulatory agencies in the world can ensure the adequacy of medicines and vaccines and as the pandemic revealed deficiencies in the existing health care systems, experts are expressing fears that without proper actions the world risks a parallel pandemic of counterfeit drugs and pharmaceutical products [17,40,45].

#### 5. Measures and actions before and during the pandemic

This problem was first addressed in 1985 (Conference of Experts on the Rationale use of Drugs, Nairobi) [46] and various initiatives have been taken since then to fight the counterfeit of pharmaceuticals crime. In 1992, the WHO released the "WHO Guidelines for the Development of Measures to Combat Counterfeit Drugs" [47] and in 2006 the International Medical Products Anti-Counterfeiting Taskforce (IMPACT) was launched to establish coordination between members of international organizations, enforcement agencies, industry, and nongovernmental organizations to tackle the increased criminal networks and internet sources in which fake health products are gaining popularity [48]. WHO launched its Global Surveillance and Monitoring System for substandard and falsified medicines, vaccines and in-vitro diagnostic tests in July 2013, and in 2017 reported a three-step strategy to counter fake pharmaceuticals: prevent, detect and respond [49,50]. In 2019 the United Nations issued a guide to illustrate the basic concepts on combating falsified medical product related crime [1].

Law enforcement and drug control agencies at the local and international level work closely together to combat trafficking of counterfeit pharmaceuticals [51]. More than 18 million atorvastatin tablets sold in the United Kingdom were recalled after the detection of a smuggling operation that compromised the brand name Lipitor drug supply [52,53]. Approximately 2 million oral contraceptive tablets without active ingredients in them were intercepted as they were being smuggled into the United States [52]. In September 2019, the US Food and Drug Administration (FDA) reported that 1159 lots of valsartan, losartan, and irbesartan had been recalled because of high levels of N-nitrosodiethylamine (NDMA) [54]. In the detection of counterfeits INTERPOL also plays an important role. In March 2020, INTERPOL seized more than 34,000 counterfeit medical goods after targeting the online sale of illicit medicines and medical devices related to COVID-19 (global operation Pangea XIII) [13]. It is supporting collaboration between health regulators, customs, police, experts in countering illicit trade, financial crime and cybercrime, in

194 member countries, regionally as well as globally in their fight against illicit activities in the trade of pharmaceuticals [13]. Online training and webinars are also provided by INTERPOL with collaboration with the International Intellectual Property Crime Investigators College to build the skills and knowledge of agencies in combating COVID-19 crime threats [13].

Actions based on collaborations were taken by countries like the Anti-Counterfeiting Trade Agreement (ACTA) (by Australia, Canada, the EU, Japan, Mexico, Morocco, New Zealand, Singapore, South Korea Switzerland and the USA) [55], the Member States of the European Union with the Directive 2011/62/EU [56], as well as agencies like the FDA [57], the US Agency for International Development (USAID) [58] and the European Medicines Agency (EMA) [59]. Activities and programs undertaken by UNICEF, the United Nations Population Fund, the Global Fund, Bill & Melinda Gates Foundation focus on supporting product traceability with the use of new technologies [17]. Furthermore, some programs specifically aim to strengthen regulatory agencies in LMIC in order to ensure access to appropriate, safe, affordable, and quality-assured medicines [60].

Legitimate pharmaceutical manufacturers play also an important role in the fight against the counterfeiting of pharmaceuticals. There are ongoing industry efforts through dedicated internal anti-counterfeit teams for tackling counterfeit medicine across the globe. These teams are dedicated in deterring illegal counterfeit medicines trade by advancing detection with new technologies and implementing new strategies and techniques that make the production of counterfeits more difficult but their detection easier. Moreover, strong working relationships have been built between the pharmaceutical industry, the law enforcement agencies and regulatory or health authorities, in the attempt to trace counterfeit products, as well as, manufacturers and distributors [61,62].

Detection of counterfeit pharmaceuticals is also a crucial step in reporting and policy making. Various methods to detect counterfeits exist, with strengths and weaknesses in applicability, reliability, and cost [15]. The first step is visual inspection of packaging to provide information on suspected products, followed by scanning barcodes and seals that easily detect unlabeled or wrongly labeled medicines [14]. More sophisticated methods also exist like the analysis of primary packaging by spectroscopic techniques such as IR and Raman in combination with optimized chemometric models [14]. Subsequent (chemical) analysis is often required with methods, based on LC- or GC-MS, to confirm falsification of suspected samples [14].

Finally, public awareness campaigns have been also used in the fight against counterfeit drugs, like the initiative taken by the United Nations Organization for Drugs and Crime (UNODC) named "Counterfeit: Don't Buy into Organized Crime", as well as the "INTERPOL-Checkit" (I-Checkit), which provides the general public with a product verification tool to check if products are real or counterfeit [7]. Under Operation Pangea XIII, INTERPOL member countries also reached out to the general public—through videos, brochures, exhibitions and talks at hospitals and schools—to raise awareness of the dangers of buying pharmaceuticals from unregulated online sources [63].

## 6. Recommendations, perspectives and limitations

Studies conducted by WHO, UNODC, OECD and other international bodies showed that the absence of a comprehensive legal framework is responsible for the flourishing of the adulterated medicines trade especially in low-income countries [16]. Therefore, it is essential that every country examine their existing drug control laws for adequacy in preventing their trafficking [24]. If the laws are inadequate, legislation needs to be quickly strengthened in order to assist in the detection and eradication of fake pharmaceuticals and the criminal groups behind them [24]. On the other hand due to globalization it is also essential that both domestic and international

law be engaged to combat counterfeit medical crime [16]. While the production of counterfeit pharmaceuticals will be more effectively regulated by domestic laws, exports would be regulated more effectively by international laws in order to ensure cooperation [16].

Generally, one of the most efficient tools for the eradication of counterfeit medicines crime is having in place an efficient enforcement regime [10,16]. Collaboration between law enforcement agencies is also essential especially in the form of exchanging criminal intelligence relating to transnational organized crime groups involved in counterfeit activities [24]. The continuous monitoring of the dark web is also needed as the online shadow economy has evolved during the COVID-19 pandemic [8]. Moreover strict and tough punishments should be implemented across all countries on criminals manufacturing and marketing counterfeit pharmaceuticals [4].

While this problem has been compounded by the COVID-19 global pandemic, the reality is that each country needs to develop more than adequate laws. They need to develop a comprehensive national strategy, internationally harmonized, by taking into account the seriousness of the current health crisis [3,24]. However, even countries with a highly evolved drug regulatory system may find it challenging to design and implement appropriate strategies to combat this problem in the time of the pandemic [24]. Towards this approach all actions and measures, in order to be successful, should include a whole of government and society approach and strong political will to implement robust regulations that overcome difficulties [17,24]. Building collaborations between countries, governments, organizations, public agencies, researchers and private sector are very essential [4,17,64]. Producers and governments should be active and work closely together either by improving investment capital and infrastructure to encourage small- and medium-sized drug manufacturing companies to meeting international standards or by supporting producers to develop techniques that improve the tracking and tracing of their products [11,17]. International regulatory agencies should all work to strengthen national and international pharmaceutical governance, to ensure adequate funding for monitoring distribution of falsified products and to initiate and/or assist in coordinating the information-sharing process [17]. Moreover, high-income countries need to support low- and middle income countries in research and training [4]. Enhanced global cooperation can also help countries secure critical medicines, especially in light of challenges caused by border closures [10].

The pharmaceutical industry should be fully involved in the fight against falsified drugs especially during the age of COVID-19. One way is by making the prices of authentic medical products more affordable especially in low- and middle-income countries [4]. Moreover, security of supply chains should be ensured through implementation of good distribution and warehousing practice [17]. Furthermore, it is very important to diversify the sources of pharmaceutical supply to ensure continuity of supply across the globe [10]. For this reason there are ongoing industry efforts to support initiatives to maximize domestic productions of raw materials to prevent disruption to the supply chain in the future [17]. The risk of disruptions in the supply chains could be alleviated by the globally distributed manufacture so that when a crisis affects supply in one part of the world, the rest of the world could make amends for the lost production by increasing theirs [10]. Furthermore, in order to preserve a strong and secure supply chain, transparency is needed. Meaning that regulators need to monitor manufacturing sites of medicines and ingredients and keep track of their route through the supply chain in order to ensure that the supply of quality medicines is not being jeopardized by sudden disruptions [10]. Unfortunately, for the time being, this information is restricted and inconsistent [10]. As a result efforts should be made towards increasing transparency across the supply chain globally.

**Table 1**  
Guidelines for potential consumers as were given by the INTERPOL [13].

Never buy	Only buy
From unknown websites or in a marketplace	Medicines prescribed by doctors
From pharmacies making promises like “too good to be true”, “cures all types” of a major illness, “money-back guarantee”, or “no risk”	From websites that require prescription and have authenticity certificate
Substantially cheaper product, it is likely to be a fake	After checking the price against usually bought products from reputable providers
If the product contains different ingredients, claims to have different properties, has a different shape, is not correctly labeled, has an out-of-date or missing expiry date, or the packaging looks badly made	After comparing the medicine against the usually prescribed one

Another tool in combating fake drugs and pharmaceuticals is raising public awareness, through educational campaigns, regarding medicine quality and the risks generated from using counterfeit health products [4,17,65]. In Table 1, are presented the guidelines given by the INTERPOL for safely buying prescription medications [13]. At this point, it should be highlighted that this advice largely applies to Prescription Only Medications (POM). Other classes of medications exist, such as in the UK there is also Pharmacy only medications (P) which can be dispensed by pharmacist without a prescription and General Sales List (GSL) which can be bought from pharmacies and supermarkets in some countries [66]. Moreover, the issue of weak governance in many countries causes the dangerous practice of allowing non-trained individuals who are not pharmacist or pharmacy technicians to be allowed to work in pharmacies and dispense medications. Therefore, it is very important people not only to be educated in safely purchasing medicines and medical supplies but also in recognizing pharmacists as the best suited individuals to provide trusted advice regarding medications [67]. Furthermore, people should be educated in distinguishing data based information from assertions without evidence to back them up especially in medical related cases [17]. Such assertions could only confuse the general public and make people lose confidence to health care systems and science.

In achieving the goal of eradicating fake pharmaceuticals trade, one should take into consideration the implementation of appropriate detection technologies to enable easy, quick and accurate identification of counterfeit or authentic products [17,65]. These technologies are not only an effective tool in protecting public health through detection but also in generating useful data mostly needed to quantify and evaluate the problem [4,68–71]. Therefore, countries need to invest in research and technologies focused in the detection of counterfeit drugs and pharmaceuticals, not only for identifying and eliminating them from the market but also for providing stakeholders with valuable and reliable information for policymaking. It should be mentioned that all medicines are not possible to be tested analytically to verify authenticity or falsification. The first step is a medicine to be identified as dubious by its appearance or by the reporting of adverse health effects or internationally observed trends in falsified medicines. The next step is the suspicious medicine to be tested with analytical procedures [4,14]. It becomes obvious that in detecting counterfeit medical products not only technologies are useful but also having adequate reflexes in information exchange, in national and international level, in order data in incidences, trends, adverse effects and seizures of counterfeits to be shared fast enough to save lives by preventing them from flooding the market.

## 7. Conclusion

It is more than clear that there is an imperative need for targeted actions from prevention to suppression. The first essential step is ceasing counterfeit products from entering the supply chain. Should that not be fulfilled, measures targeting effective detection of circulating counterfeit pharmaceuticals must follow. Finally and foremost specific responses should address this health threatening matter, in multiple levels with the cooperation of all involved actors.

On a national level, governments have been cooperating with industry to combat counterfeit trafficking, yet this cooperation can be fortified and intensified with decisive initiatives. Actions must be taken towards robust legislative measures in order to strengthen regulatory capacity. Enforcement measures and local surveillances are essential tools to control the infiltration of fake products in the pharmaceutical market. Furthermore, the involvement of science through research in the field of falsified medicines, as well as the society as a whole through raising public awareness could create a more comprehensive approach. On an international level, many initiatives are underway to tackle the growing trend, underlining the necessity for transnational actions. One cannot emphasize enough the need for international cooperation, harmonized pharmaceutical governance and strategies. Only collaboration and initiatives between countries can lead to solutions that can effectively restrict the proliferation of counterfeit pharmaceuticals.

In the age of COVID-19 pandemic the sudden and growing need for specific medical supplies in combination with the constant disruption of the supply chain processes had worsened the situation. It was highlighted that now more than ever policy makers and regulators should support internationally harmonized strategies, collaborations and investments more concentrated on assuring that quality medical products are being accessible to the general public in each country. Towards this direction useful tools would be the use of advanced technologies, the increase of manufacturing sites around the world as well as the enhancement of domestic manufacturing for the production of medical products in order to build a resilient supply chain to global crises or local disasters. Moreover, efforts should be focusing on close monitoring the processes of manufacture and sale thus creating a transparent and secure supply chain, globally. The pandemic also emphasized the necessity for robust educational campaigns in order to inform the public about the risks of using counterfeit drugs and to restore faith to pharmaceutical industry and science.

Considering all the aforementioned describing the situation before and during the pandemic, it was made obvious that the synergy between stakeholders in an international level is the key to viable solutions, and the implementation of a targeted holistic approach is the path to be followed. While all the above, may not fully eliminate the problem, they should substantially reduce the exposure of populations to the risks associated with the trafficking and use of counterfeit drugs and pharmaceuticals, in the time of COVID-19 and beyond.

## CRedit authorship contribution statement

**Kalliroy Ziavrou:** Investigation, writing. **Stephen Noguera:** Methodology, MS reviewing. **Vassiliki Boumba:** Methodology, Supervision, Writing- Reviewing.

## Conflict of interest

The authors declare no conflict of interest for the submitted manuscript entitled: “Trends in counterfeit drugs and pharmaceuticals before and during COVID-19 pandemic”.

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