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USING BLOCKCHAIN TECHNOLOGY TO TRACK DRUGS IN THE HEALTHCARE SUPPLY CHAIN

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ABSTRACT:- Complex, cross-organizational, geographical supply networks sustain critical healthcare services. Complex systems can produce inaccurate, opaque, and unreliable data. Supply chain delays cause counterfeit drugs to damage people and cost the healthcare business. Multiple studies emphasize pharmaceutical supply chain tracking and tracing. Pharmaceutical supply chains need end-to-end product tracking to prevent counterfeits and ensure safety. Most centralized healthcare supply chain track and trace systems compromise privacy, transparency, and authenticity. Healthcare supply chain items are tracked using Ethereum blockchain smart contracts and decentralized off-chain storage. This secure, immutable transaction history eliminates middlemen and ensures data provenance for all smart contract participants. Exploring solution technique and system architecture. We test, validate, and assess the system's cost and security to improve pharmaceutical supply chain traceability.

***INDEX TERMS*:-** Blockchain, drug counterfeiting, traceability, healthcare, supply chain, trust, security.

1. INTRODUCTION

A complex healthcare supply chain includes basic material suppliers, manufacturers, distributors, pharmacies, hospitals, and patients. This network makes supply tracking difficult due to a lack of information, centralized control, and stakeholder competition. Complexity makes it easier for counterfeit drugs to enter the healthcare supply chain and causes inefficiencies like COVID-19. Fake drugs are intentionally created or labeled to look authentic. These drugs may have weak active pharmaceutical ingredients (API), the wrong API, the wrong dosage, a low-quality API, contaminants, or be repurposed, old products. Some counterfeit medications have inadequate formulations and production.

Pharmaceuticals in developing nations are 30% counterfeit, according to the Health Research Funding Organization. A new WHO report says counterfeit drugs are a leading cause of death in developing nations, especially among children. Counterfeit pharmaceuticals damage people and cost the pharmaceutical business. The US pharmaceutical industry loses money annually due to counterfeit drugs. Figure 1 shows a typical pharmaceutical supply chain distribution method. API providers build FDA-approved drugs. Drug manufacturers and repackagers package many medications. Based on demand or secondary distributors (if large quantities), the main distributor buys and distributes many Lots to pharmacies. Distributors and third-party logistics providers like UPS and FedEx use their own vehicles to distribute pharmaceuticals.

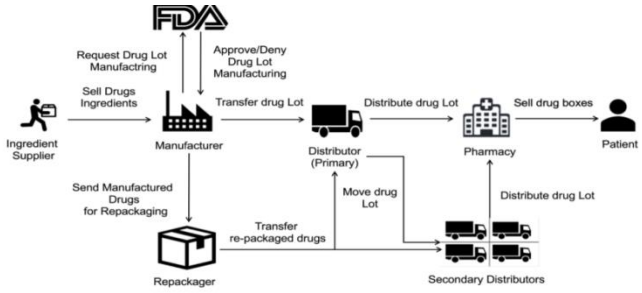

FIGURE1. Drug supply chain stakeholders and their relationships.

Due to the complex healthcare supply chain, counterfeit drugs are frequent. Complexity allows drugs to bypass dissemination. Healthcare supply chain goods must be monitored, regulated, and traceable to prevent counterfeits.

Countries encourage and regulate drug traceability. View America. The Drug Supply Chain Security Act requires pharmaceutical companies to track US-distributed prescription medications electronically and digitally. For eight years, China has compelled all medicine supply chain stakeholders to record pharmaceutical product information when transporting pharmaceuticals between warehouses. Pharmacy ownership and legitimacy

are verified.

Like a linked list, each blockchain node holds the genesis block and all blocks connected to the longest chain. Many key IoT, e-Government, and electronic document management apps have been developed recently. It employs blockchain's peer-to-peer ledger and hash-based self-cryptographic validation.

One of the first blockchain-based pharmaceutical supply chain traceability experiments is described. Rewriting blocks affect records from earliest to latest transaction. Due to pharmaceutical supply chains and block chains, we recommend end-to-end drug traceability. Other models just include suppliers, manufacturers, and wholesalers, whereas our drug supply chain includes FDA, supplier, manufacturer, distributor, pharmacy, and patient. Pharmacists are external, unlike the pharmaceutical supply chain.

Our stakeholder, on-chain resource, smart contract, and decentralized storage system linkages are obvious. We created terminology to reduce confusion without addressing stakeholder interactions. SMS and real-time smart contract tracking remove delays. Every medication lot has a unique smart contract that notifies DApp users of ownership changes. Distributor, producer, and supplier smart contracts require drug receipt verification [20]. Incorrect and sluggish immutable ledger data. Our final evaluation was the method's cost-benefit and supply chain security.

2. RELATED WORK

We focus on anti-counterfeiting healthcare supply chain product traceability strategies. We separated blockchain and non-blockchain methods.

TRADITIONAL EFFORTS FOR DRUG TRACEABILITY accessing all object information via formal identification throughout its existence. Any traceable supply chain item is resource. Traceability tracks transactions and TRUs. The TRU must be distinguished in numerous ways for supply chain traceability. TRUs, their relationships, and their attributes are found through traceability systems. Previous supply chain management solutions collected product data via barcodes, RFID IDs, WSNs, and EPCs. Supply chain activities track ownership changes with GS1 barcode data. When stakeholders report product possession using a GDSN-enabled smartphone app, patients can verify authenticity. Hospitals and pharmacies scan warehouse barcodes for product quality.

BLOCKCHAIN-BASED SOLUTIONS FOR DRUG TRACEABILITY

Traditional centralised pharmaceutical supply chain traceability solutions are opaque, allowing the central authority to update information without notifying stakeholders. Immutability, provenance, and transaction records are blockchain benefits. Transactional enterprises use immutable blockchain. Confusion around transparency and traceability. Top-level supply chain data is usually transparent. Map supply chains using product components, facility locations, supplier names, etc. Traceability entails choosing a component, implementing partner communication standards, generating and collecting trustworthy data, storing data on a platform, and sharing data. Gathering granular data demands supply chain expertise. Decentralized, verified pharmaceutical drug tracking uses blockchain cryptography extensively. Mettler promised blockchain-based healthcare solutions without demos or technical details. Kurki suggested blockchain could help pharmaceuticals. Just ideas were explained. Muniandy and Ong Tze Ern showed an Ethereum-based anti-counterfeiting tracking system. Poor implementation and evaluation devalue smart contracts.

Huang et al. Drug ledgers generate approved and confidential stakeholder traceability data and ensure system resilience. Drug supply chain transactions are tracked. Drug ledger packing, repackaging, and unpackaging require extended UTXO data. Recent research examined UTXO data structure programmability, storage cost, and state space consumption.

His name is Faisal. Hyperledger was suggested for medicine supply chain tracking. Despite their untested method and limited network, the authors show greater throughput, latency, and resource utilization. The ad addressed blockchain scaling, a popular literary topic. Hulse Apple bit money

safeguarded chain transactions and hashed data with a second blockchain. Each product has a blockchain record, thus private keys cannot be modified.

3. BLOCKCHAIN-BASED DRUG TRACEABILITY SYSTEMFOR PHARMACEUTICAL SUPPLY CHAINS

Traditional centralised pharmaceutical supply chain traceability solutions are opaque, allowing the central authority to update information without notifying stakeholders. Immutability, provenance, and transaction records are blockchain benefits.

Openness/traceability misunderstanding. Top-level supply chain data is usually clear. Use product components, facility locations, supplier names, etc. to map supply chains. Traceability requires picking a component, implementing partner communication standards, generating and collecting trustworthy data, storing data on a platform, and sharing data. Gathering granular data requires supply chain expertise.

Huang et al. With approved and confidential stakeholder traceability data, drug ledgers boost systems. Drug supply chain transactions are tracked. Extended UTXO data is needed for drug ledger packing, repackaging, and unpackaging. Recent research examined UTXO data structure programmability, storage cost, and state space utilization.

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Distributed ledger medication supply chain research. Cisco, IBM, Accenture, Intel, Bloomberg, and Block medically date Arsene source and position. Blockchain verifies DSCSA and industry compliance. Ethereum, Hyperledger, and Quorum tracked Farma Trust drugs. Limited transaction sequencing and policy enforcement Utility of Quorum. To conclude production, distributors bundle pharmaceutical batches.

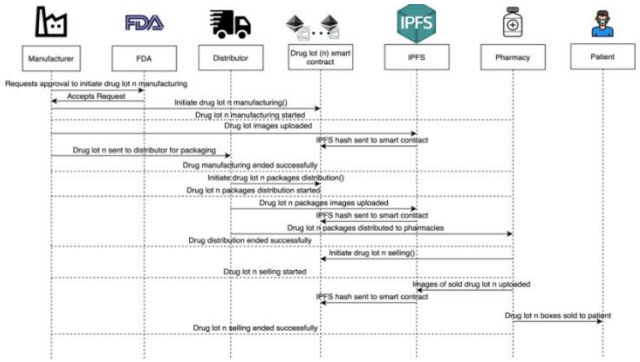

FIGURE 3. Sequence Diagram showing interactions among the participating entities of the smart contract

Distribution: Sequence Diagram depicting smart contract interactions. The distributor will upload a picture to IPFS, which will transmit a hash to the smart contract, after packaging the medicine Lot. Pharmacies receive drug lot containers after this phase, stopping distribution.

Sale/Consumption The sequence diagram finishes with pharmacy-patient contacts. The drugstore will sell Lot boxes and alert suppliers. Uploading a photograph of the sold medicine container to IPFS will hash the smart contract. The patient will acquire the Lot bundle, concluding the sale.

COMPARISON OF PROPOSED SOLUTION WITHEXISTING SOLUTIONS

In this part, we compare the proposed traceable pharmaceutical medication supply chain solution against relevant systems. Table 1 summarizes this analysis.One entity cannot influence data in the decentralized solution. Another key element of

TABLE 1. Comparison between our proposed solution and thenon-blockchain solutions.

	Smart-Track	Data-Matrix Tracking System	NFC	Proposed Solution
Decentralized	No	No	No	Yes
Resilience	No	No	No	Yes
Integrity	No	No	No	Yes
Tracking and Tracing	Yes	Yes	Yes	Yes
Security	No	No	No	Yes
Transparency	No	No	No	Yes

Decentralization lowers single failure points, making our solution resilient. The immutability of blockchain secures data. Entered ledger data is final. Decentralized data is safe because no one can change it. Transaction transparency is key for supply chains. All participants can securely view confirmed transactions in our system. All Table 1

solutions have track and trace, but other functions such

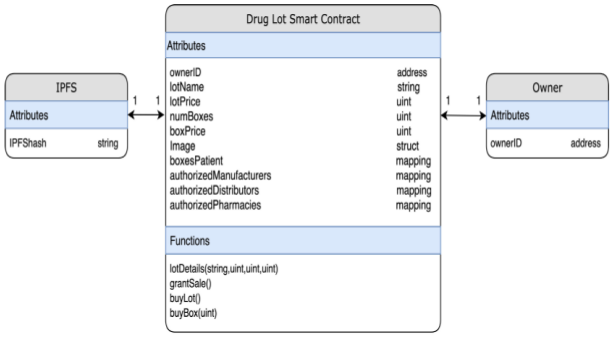

TABLE 2. Comparison between our proposed solution and otherblockchain-based solutions.

	Our Soluition	Huang et al [34]	Faisal et al [32]
Blockchain Platform	Ethereum	Bitcoin	Hyperledger-Fabric
Mode of Operation	Public Permissioned	Public Permissioned	Private Permissioned
Currency	Ether	BTC	None
Off-Chain Data Storage	Yes	No	No
Programmable Module	Smart Contract	None	Docker Container

Blockchain uses Hyperledger-Fabric. Our solution employs public permissions, while Hyperledger-fabric uses private rights. Our method uses Ethereum Ether.

4. IMPLEMENTATION OF PROPOSED TRACEABILITY SYSTEM

The solution's development employs Ethereum. Anyone can use Ethereum, a permissionless blockchain. Users may debug and test Solidity code with Remix IDE, a web-based smart contract development environment. The whole code1 is public.

IMPLEMENTATION DETAILS

The manufacturer will initiate a pharmaceutical Lot event for all supply chain partners utilizing the smart contract. New network users can follow any drug Lot because the ledger always records events. IPFS Lot photos can be evaluated by collaboration partners. The Lot must be wrapped before sale, and the manufacturer will notify participants. Lot sales show the Lot owner. For simplicity, the medical Lot smart contract ignores FDA approval before implementation.

Figure 4 displays smart contract entity relationships. Figure 4 shows Ethereum-based owner IDs activating smart contracts. Due to their single owner ID, drug lot smart contracts are addresses, not maps. Blockchain records Medicine Lot ownership changes. Smart contracts display medical lot names, pricing, packaging, and photos. Three mappings for approved entities exist.

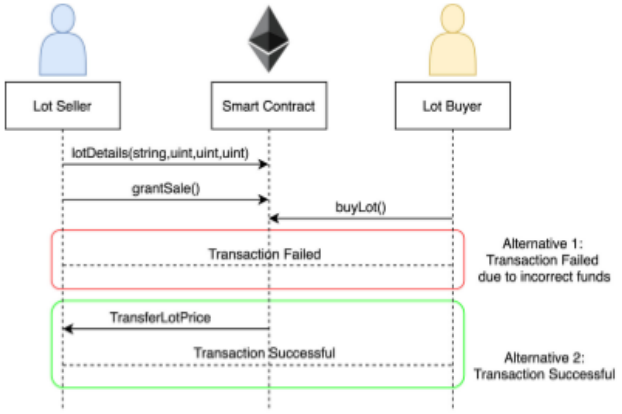

FIGURE 5. Function calls and events for two different scenarios for Lotsale.

Smart contracts for drugs, distribution, and industry. Lot manufacturing and sale are smart contract features. Name, price, boxes, and price are manufacturing lot data. Manufacturers can upload photos for image hash retrieval using IPFS. Each Lot uploads one image, therefore IPFS and smart contract are 1:1.

Negotiating lot acquisition with vendor. Good supply chains include pharmacy, distribution, and manufacture. Figure's sequence diagram depicts both circumstances. Sellers store chain hash, lot info, and maybe an IPFS photo. Grant Sale announces lot sale. Lot purchasers require 2 things. The buyer must have enough money and the function's executor cannot have the Lot's Ethereum address. This leaves two options. If the buyer can't afford the Lot, the deal fails. Buyer is compensated for matching Lot price. Five is comparable to six with minor differences. Buyers order Lot cartons. Pharmacy-patient pharmaceutical delivery lines usually do this. Stores fulfill BuyBox orders.

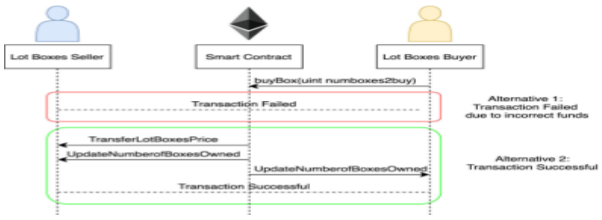

FIGURE 6. Function calls and events for two different scenarios for lotboxes sale.

- Two results. Transaction fails if funds don't match box price. Sellers get the box price if delivery fulfills demand. Quantity bought will update both parties' box counts.

➢ To demonstrate intelligent controller duties, we discuss our solution's algorithms. Sellers and buyers need approval.

Algorithm 1 Creating a Lot in Smart Contract

Input: lotName, lotPrice, numBoxes, boxPrice, IPFShash, Caller, OwnerID
Output: An event declaring that the Lot has been manufactured
An event declaring that the image of the Lot has been uploaded
Data:
lotName: is the name of the Lot
lotPrice: is the specified price of the Lot
numBoxes: is the total number of boxes within a Lot
boxPrice: is the price of each box within a Lot
IPFShash: is the IPFS hash of the Lot image
ownerID: is the Ethereum address of the owner of the Lot
initialization;
if *Caller* == *ownerID* **then**
  Update *lotName*
  Update *lotPrice*
  Update *numBoxes*
  Update *boxPrice*
  Add *IPFShash*
  Emit an event declaring that the Lot has been manufactured
  Emit an event declaring that the Lot image has been uploaded to the IPFS server
else
  Revert contract state and show an error.

Algorithm 2 Granting Lot Sale

Output: An event declaring that the Lot is for sale
initialization;
if *Caller* == *ownerID* **then**
  Emit an event stating that the Lot is up for sale
else
  Revert contract state and show an error.

Intelligent contract. When a Lot is sold, the buyer may trust the vendor and expect delivery. • Buying Lot Boxes: Algorithm 4 is similar to 3, but somewhat different. Start with Step 3, except the buyer must give the Lot box tally. Customer transfers must match the quantity of boxes times their price. This function modifies buyer address and box purchase mapping when called.

TRACEABILITY ANALYSIS OF THE PROPOSED SOLUTION

This section explains Lot's drug potency validation. Every medicine Lot

Algorithm 3 Buying Lot

Input: ownerID, Buyer, Seller, Transferred Amount, lotPrice
Output: An event declaring that the Lot has been sold
Data: *ownerID*: The Ethereum address of the current Lot owner
Buyer: The Ethereum Address of the buyer
Seller: The Ethereum Address of the Seller
Transferred Amount: The amount transferred to the function
lotPrice: The price of the Lot
initialization;
if $Buyer \neq Seller \wedge TransferredAmount = lotPrice$ **then**
  Transfer the price of the Lot to the seller
  Update ownerID by replacing the seller Ethereum address to the buyer Ethereum Address
  Emit an event declaring that the Lot has been sold
else
  Revert contract state and show an error.

Custom smart contracts start and log ledger events. Separate Ethereum addresses for pharmaceutical lots. Duplicating each drug's Ethereum address is tedious and error-prone. Smartphones scan QR codes. Smartphones scan 4000-character 2D QR codes. Ethereum addresses generate scannable QR codes. Patients can buy drugs using QR codes. Pharmacological effectiveness is seen in Figure 7. Scan the drug's QR code with D App and connect to a local or remote Ethereum node with web3j. D App uses Infura's JSON-RPC to convert QR codes to Ethereum addresses. The Ethereum node ledger copy speeds consumer setup. Ethereum node gateway applies Lotto smart contract Ethereum address to ledger events. The smart contract's Ethereum address and event name can validate Lot's origin. This immutable blockchain validates drug authenticity via event filtration. Ethereum pharmacy opens lot Sold.

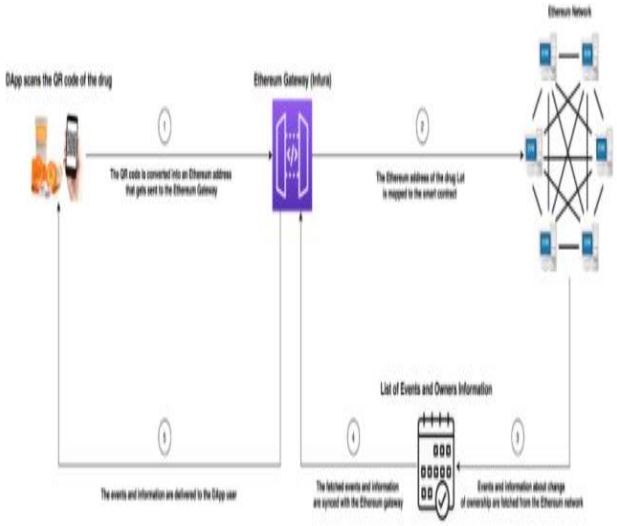

FIGURE 7. Application use case of the proposed blockchain-based solution.

Algorithm 4 Buying Lot Boxes

Input: ownerID, Buyer, Seller, Transferred Amount, boxPrice, numBoxes, numBoxesToBuy, Transferred Amount, boxesPatient
Output: An event declaring that the Lot boxes have been sold
Data: *ownerID*: The Ethereum address of the current Lot owner
Buyer: The Ethereum Address of the buyer
Seller: The Ethereum Address of the Seller
Transferred Amount: The amount transferred to the function
boxPrice: The price of the Lot box
numBoxes: The total number of boxes in the Lot
numBoxesToBuy: The number of boxes the buyer wants to buy
boxesPatient: Maps the number of boxes bought to the buyer address
initialization;
if $Buyer \neq Seller \wedge TransferredAmount = numBoxesToBuy * boxPrice$ **then**
  Transfer the price of the boxes to the seller
  Update ownerID by replacing the seller Ethereum address to the buyer Ethereum address
  Update numBoxes owned by the seller by decreasing the sold amount from it
  Update boxesPatient by assigning the purchased amount to the buyer address
else
  Revert contract state and show an error.

Figure 7 displays Ethereum data sharing. An immutable ledger replica verifies data integrity at each network node. This sample shows how well our technology tracks pharmaceutical supply chain medications. Events and ownership changes from Ethereum will be synchronized with Infura and shown in the DApp. It automates processes with web3j, JSON-RPC, and Infura on Ethereum.

5. TESTING AND VALIDATION

The Remix IDE in-browser development and testing environment validates Ethereum smart contracts. The Ethereum addresses of three participants are in Table 3.


```
"from": "0x5e72914535f202659083db3a02c984188fa26e9f",
"topic": "0x44c99celec0af6519400dc5641e20fd507c596f90096ffe116181619d7ab1a25",
"event": "lotManufactured",
"args": {
        "0": "0xCA35b7d915458EF540aDe6068dFe2F44E8fa733c",
        "manufacturer": "0xCA35b7d915458EF540aDe6068dFe2F44E8fa733c",
        "length": 1
```


FIGURE 8. Successful execution of lotDetails Function.


```
"from": "0x5e72914535f202659083db3a02c984188fa26e9f",
"topic": "0x15a51b79663b36aa87b7e256eddbad58070b43d374c4294e41b9e76ad43a4c04",
"event": "lotSale",
"args": {
        "0": "Aspirine",
        "1": "200",
        "2": "1000000000000000000",
        "3": "1000000000000000000",
        "_lotName": "Aspirine",
        "_numBoxes": "200",
        "_lotPrice": "1000000000000000000",
        "_boxPrice": "1000000000000000000",
        "length": 4
```


FIGURE 9. Successful execution of grantSale Function.


```
"from": "0x5e72914535f202659083db3a02c984188fa26e9f",
"topic": "0xeb373dc4c684e4ae6135618e7fc15d654b409d8071dc8126b4a5d18ac86590db",
"event": "lotSold",
"args": {
        "0": "0x14723A09ACff6D2A60DcdF7aA4AFf308FDDC160C",
        "newownerID": "0x14723A09ACff6D2A60DcdF7aA4AFf308FDDC160C",
        "length": 1
```


FIGURE 10. Successful execution of buyLot Function.


```
"from": "0x5e72914535f202659083db3a02c984188fa26e9f",
"topic": "0x82c28ddbad097bd1003a55cdb6788f38fbe3033fa91c813a8a00652716c0d45b",
"event": "boxesSold",
"args": {
        "0": "50",
        "1": "0x14723A09ACff6D2A60DcdF7aA4AFf308FDDC160C",
        "_soldBoxes": "50",
        "newownerID": "0x14723A09ACff6D2A60DcdF7aA4AFf308FDDC160C",
        "length": 2
```


FIGURE 11. Successful execution of buyBox Function.

every parcel. Figure 8 demonstrates successful function execution, logs, and occurrences.

grant Sale: The Permit Sale function tells all entities that the manufactured Lot is for sale, a simple yet crucial step. Figure 9 displays a successful function call.

buy Lot: This function buys the Lot from Participant1 using Participant2 (Table 3 displays the Ethereum address). Figures 8 and 10 illustrate Participant1 transferring 1Ether and the function's successful execution.

6. CONCLUSION

We studied the issues of drug traceability in pharmaceutical supply chains and its importance in regulating counterfeit drugs. We designed and tested a pharmaceutical supply chain blockchain tracking system. Our solution combines cryptographic principles in blockchain technology to produce tamper-proof supply chain records with Ethereum smart contracts to automate event recording for all parties. Our gas-efficient smart contract implementation was showcased. Our technology protects transaction data from fraud in multiparty contexts like the pharmaceutical

company.

REFERENCES

1. Shortage of Personal Protective Equipment Endangering Health Workers Worldwide. Accessed: Jun. 3, 2020. [Online]. Available: https://tinyurl. com/v5qauvp
2. W. G. Chambliss, W. A. Carroll, D. Kennedy, D. Levine, M. A. Moné,
3. L. D. Ried, M. Shepherd, and M. Yelvigi, ‘‘Role of the pharmacist in preventing distribution of counterfeit medications,’’ J. Amer. Pharmacists Assoc., vol. 52, no. 2, pp. 195–199, Mar. 2012.
4. Z. RJ, ‘‘Roles for pharmacy in combating counterfeit drugs,’’ J. Amer. Pharmacists Assoc., vol. 48, pp. e71–e88, Jul. 2008.
5. P. Toscan. The Dangerous World of Counterfeit Prescription Drugs. Accessed: Jun. 3, 2020. [Online]. Available: http://usatoday30. usatoday.com/money/industries/health/drugs/story/2011-10-09/cnbc- drugs/50690880/1
6. T. Adhanom. (2017). Health is a Fundamental Human Right. Accessed: May 26, 2020. Available: https://www.who.int/mediacentre/news/ statements/fundamental-human-right/en/
7. Growing Threat From Counterfeit Medicines, World Health Organization, Geneva, Switzerland, 2010.
8. D. Bagozzi. (2017). 1 in 10 Medical Products in Developing Countries Is Substandard or Falsified. Accessed: Jun. 3, 2020. https://www.who.int/news-room/detail/28-11-2017-1-in-10-medical-products-in-developing-countries-is-substandard-or-falsified
9. T. Guardian. (2017). 10% of Drugs in Poor Countries Are Fake, Says WHO. Accessed: Jun. 3, 2020. [Online]. Available: https://www.theguardian.com/global-development/2017/nov/28/10-
10. A. Seiter, ‘‘Health and economic consequences of counterfeit drugs,’’ Clin. Pharmacol. Therapeutics, vol. 85, no. 6, pp. 576–578, Jun. 2009.