Medicine Tracking System Using Blockchain

A PROJECT REPORT

Submitted by,

Ayush Aryan – 20211ISE0009
Bushra Begum – 20211ISE0053

Under the guidance of,

Dr.G Shanmugaratinam

in partial fulfillment for the award of the degree of

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IN

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AT

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PRESIDENCY UNIVERSITY

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

CERTIFICATE

This is to certify that the Project report **Medicine Tracking System Using Blockchain** being submitted by Ayush Aryan and Bushra Begum bearing roll number(s) 20211ISE0009 and 20211ISE0053 respectively, in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in **Information Science and Engineering** is a bonafide work carried out under my supervision.

18/5/2025

Dr.G Shanmugaratinam
Professor
School of CSE&IS
Presidency University

Dr. Pallavi R
Professor & HoD
School of CSE&IS
Presidency University

Dr. MYDHILI NAIR
Associate Dean
School of CSE
Presidency University

Dr. SAMEERUDDIN KHAN
Pro-VC School of Engineering
Dean -School of CSE&IS
Presidency University

PRESIDENCY UNIVERSITY

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

DECLARATION

We hereby declare that the work, which is being presented in the project report entitled **Medicine Tracking System Using Blockchain** in partial fulfillment for the award of Degree of **Bachelor of Technology** in **Information Science and Engineering**, is a record of our own investigations carried under the guidance of **Dr.G Shanmugaratinam, School of Computer Science and Engineering & Information Science, Presidency University, Bengaluru.**

We have not submitted the matter presented in this report anywhere for the award of any other Degree.

Ayush Aryan 20211ISE0009 Ayush.
Bushra Begum 20211ISE0053 Bushra Begum.

ABSTRACT

A cutting-edge technology solution called the Blockchain-enabled Pharmaceutical Supply Chain for Medicine Authentication and Counterfeit Prevention (BPSC-MAC) was created to improve pharmaceutical security, traceability, and authenticity. The system makes use of blockchain, smart contracts, MetaMask, and Ganache to guarantee a pharmaceutical supply chain that is transparent, decentralized, and impenetrable. The possibility of fake drugs, which are a serious threat to patient safety and public health everywhere, is greatly reduced by this innovative strategy.

The issue of counterfeit medications has grown, resulting in serious health issues, a decline in customer confidence, and financial losses for pharmaceutical firms. Due to their lack of transparency and real-time tracking, traditional supply chains are susceptible to illicit distribution and counterfeiting. By documenting each transaction on an unchangeable blockchain ledger, BPSC-MAC directly tackles these issues and guarantees the security and verifiability of every medication's path from production to final consumer use. Pharmaceutical firms utilize MetaMask in this system to register medications on the blockchain, giving each one a unique digital identity. Important transaction information, including the manufacturer, production date, batch number, and distribution history, is embedded in a special QR code created upon registration. All parties involved in the supply chain, including distributors, retailers, regulators, and consumers, can use this QR code as an authentication tool to confirm the legitimacy of a medication at any point.

The system incorporates cutting-edge anti-counterfeiting techniques, such as QR codes, NFC/RFID tags, and buried serial numbers, to further strengthen security. Because of these procedures, it is very difficult for counterfeiters to copy medications and enter the market. Furthermore, by automating essential supply chain processes, smart contracts lower reliance on middlemen, reduce human error, and boost operational effectiveness. Ownership transfers, compliance audits, and inventory changes are all made possible by automated procedures.

By promoting accountability, openness, and trust, BPSC-MAC acts as a strong and expandable defence against fake medications. It draws attention to how blockchain technology can be used to protect public health, secure pharmaceutical supply chains, and guarantee stringent regulatory compliance. This approach creates a more robust, effective, and fraud-proof pharmaceutical ecosystem in addition to boosting consumer trust in the legitimacy of medications.

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Ayush Aryan
Bushra Begum

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CHAPTER 1

INTRODUCON

1.1 Introduction

An advanced and safe solution created to deal with the growing problem of counterfeit medications is the Blockchain-enabled Pharmaceutical Supply Chain for Medicine Authentication and Counterfeit Prevention (BPSC-MAC). Pharmaceutical fraud is a major global health concern that can result in financial losses, health problems, and a decline in public confidence in the pharmaceutical sector. The World Health Organization (WHO) reports that thousands of deaths occur annually as a result of almost 10% of counterfeit medications found in low- and middle-income nations. Due to their lack of openness, strong authentication procedures, and real-time tracking, traditional pharmaceutical supply chains are susceptible to fraud. Reliance on human documentation and middlemen makes it more difficult to detect and stop counterfeit medications, and centralized databases are vulnerable to manipulation. The persistent and public nature of these attacks often leaves victims with little respite, as digital harassment can be repeatedly accessed and shared, compounding its effects.

Blockchain technology offers a transparent, decentralized, and unchangeable answer to these problems. By combining blockchain, smart contracts, MetaMask, and Ganache, BPSC-MAC makes sure that all registered medications are listed on a safe ledger, guarding against counterfeiting and illegal changes. By scanning a distinct QR code connected to the blockchain, the method facilitates real-time verification, enabling all parties involved—from producers to consumers—to confirm the legitimacy of medications. This invention improves supply chain transparency, prevents data manipulation, and fortifies regulatory compliance. To show how BPSC-MAC transforms pharmaceutical supply chains for increased security and efficiency, the following sections explore the main facets of the problems associated with counterfeit medication, the function of blockchain, system design, authentication methods, and smart contract automation.

1.1.1 The Challenge of Counterfeit Medicines

A critical threat to public health, counterfeit medications can result in fatalities, negative side effects, and ineffective therapies. These counterfeit medications put customers at risk because they frequently include dangerous ingredients or the wrong quantities. Beyond health risks, pharmaceutical businesses lose billions of dollars every year as a result of counterfeit medications. Revenue is impacted, brand credibility is eroded, and regulatory enforcement is made more difficult. The inefficiencies of conventional supply chains make it difficult for governments and health organizations to uphold stringent pharmaceutical standards. These systems, which relieve human record-keeping and centralized databases, lack transparency and real-time tracking, which leaves gaps that counterfeiters take advantage of. Because of this, counterfeit medications enter the market unnoticed, endangering the safety of consumers as well as the integrity of the pharmaceutical sector.

1.1.2 Blockchain as a Solution

A decentralized, unchangeable, and transparent framework is offered by blockchain technology to reduce the danger of counterfeiting and guarantee the integrity of pharmaceutical supply chains. There is no chance of data manipulation or unauthorized changes because every transaction is forever documented on the blockchain. Additionally, blockchain provides real- time visibility, allowing producers, distributors, retailers, and consumers to follow the flow of medications at every turn. Because blockchain eliminates single points of failure, it is safer and more resistant to unauthorized changes than centralized systems, which are vulnerable to cyberattacks and data breaches. By using blockchain technology, the BPSC-MAC system establishes a completely traceable and impenetrable pharmaceutical supply chain, guaranteeing the security, transparency, and verifiability of all pharmaceutical transactions.

1.1.3 System Architecture and Functionality

To provide safe medication monitoring and authentication, the BPSC-MAC system makes use of blockchain, smart contracts, MetaMask, and Ganache. By registering medications through MetaMask, manufacturers establish a distinct online persona. A QR code including the batch number, manufacture information, and ownership data is created upon registration. From producers to distributors, retailers, and customers, this QR code facilitates smooth supply chain tracking, with every transaction being documented on an unchangeable blockchain ledger.

This stops fake medications from getting onto the market. Customers may check real-time transaction histories by scanning the QR code with their mobile devices, confirming its legitimacy before utilizing it. The BPSC-MAC system protects the pharmaceutical supply chain from fraud and unauthorized changes by guaranteeing transparency, traceability, and security.

1.1.4 Advanced Anti-Counterfeiting Mechanisms

Multiple levels of anti-counterfeiting methods are used by BPSC-MAC to further improve security, making it very difficult for counterfeiters to duplicate medications or alter information. By using dynamic QR codes that change with every transaction, the system avoids unwanted duplication or reuse. Furthermore, real-time medication tracking is made possible via Near Field Communication (NFC) and Radio Frequency Identification (RFID) tags, which aid in the detection of fake medications before they are used. The use of encrypted secret serial numbers incorporated in medication packaging is another cutting-edge security measure. By adding an extra degree of security, these serial numbers make it very difficult for counterfeiters to imitate authentic goods or alter packaging covertly.

1.1.5 Smart Contract Automation for Supply Chain Efficiency

Smart contracts are essential for automating important pharmaceutical supply chain procedures, lowering the need for middlemen, and improving operational effectiveness. These self- executing contracts are made to carry out automatic transaction execution and verification, guaranteeing safe and easy delivery of medications. Smart contracts are used during drug registration to avoid unwanted submissions by confirming manufacturer information before uploading the medication to the blockchain. Smart contracts minimize mistakes and fraud by ensuring tamper-proof ownership handovers when medications are moved between parties. Furthermore, smart contracts initiate real-time authentication checks when customers scan the QR code, enabling immediate confirmation of the legitimacy of the medication. By eliminating manual intervention, smart contracts reduce transaction costs, improve accuracy, and optimize supply chain efficiency, ultimately creating a secure, transparent, and trustworthy pharmaceutical ecosystem.

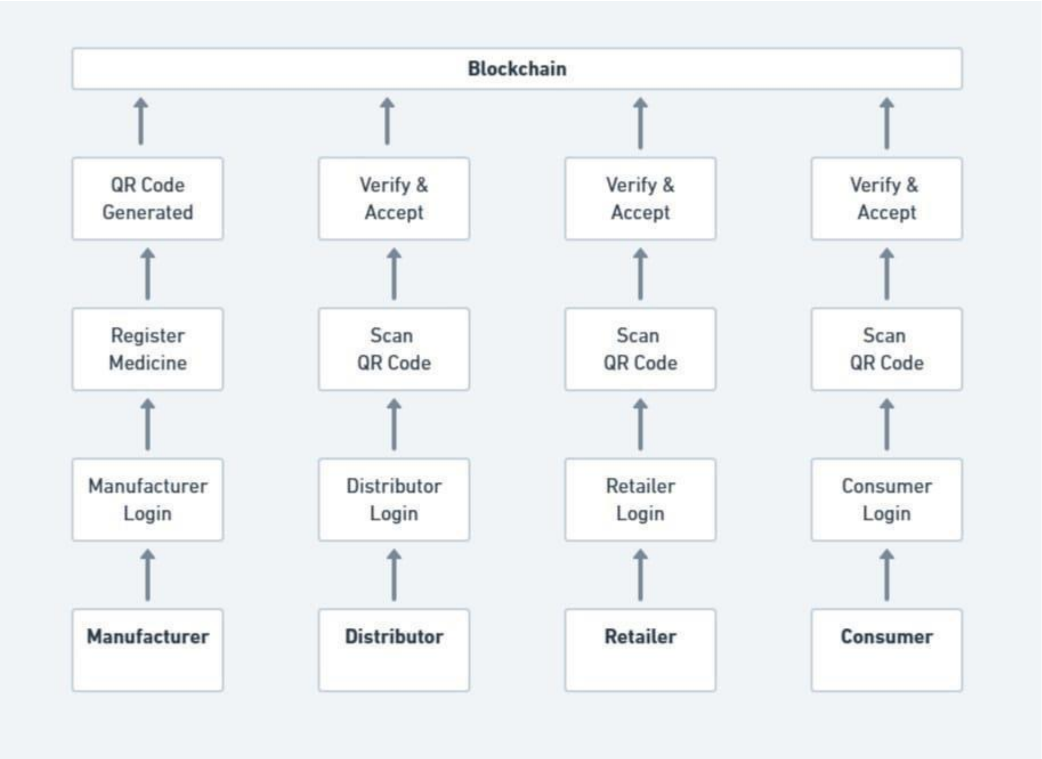

Fig 1.1 Pharmaceutical Supply Chain

The blockchain-enabled pharmaceutical supply chain method, which guarantees medication validity, security, and transparency, is seen in the image. Manufacturers, distributors, retailers, and customers engage with the blockchain systematically. Manufacturers first create a unique QR code for each product by logging in and registering medications on the blockchain. After logging in, distributors scan the QR code and confirm the medication before approving it. Similarly, before distributing the medication, shops scan the QR code, confirm its legitimacy, and accept it. Lastly, before using the medication, customers log in, scan the QR code, and confirm its authenticity. Every activity is documented on the blockchain, guaranteeing an unchangeable and impenetrable transaction history and keeping fake medications out of the supply chain.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

The supply chain for pharmaceuticals is a complicated chain of suppliers, distributors, retailers, and customers. Preventing counterfeit medications and guaranteeing drug authenticity have emerged as crucial issues in this field. Due to their reliance on human record-keeping and centralized databases, traditional supply chains are susceptible to inefficiencies, fraud, and data manipulation. Because blockchain technology is decentralised, transparent, and unchangeable, it has become a promising option.

The use of blockchain technology in pharmaceutical supply chains to improve efficiency, security, and traceability has been the subject of several research studies. However, obstacles, including scalability problems, legal compliance, and connection with older systems, provide obstacles to broad adoption. The main studies that examine blockchain's use in pharmaceutical supply chain management are reviewed in this section.

2.2 Blockchain for Supply Chain Transparency and Fraud Prevention

2.2.1 Enhancing Transparency with Immutable Records

The capacity of blockchain technology to offer an unchangeable, impenetrable record for monitoring medications is a significant benefit in the pharmaceutical supply chain. Smith et al. (2023) examined how blockchain records each transaction on a decentralized ledger, increasing transparency. This guarantees the verifiability and security of every drug's route from production to consumer purchase. By preventing unauthorized changes, the chance of fake medications reaching the market is decreased.

2.2.2 Preventing Fraud and Counterfeit Drugs

The public's health is seriously in danger from counterfeit medications, which can result in deadly outcomes and inadequate treatments. Johnson & Lee (2023) investigated how blockchain reduces fraud by facilitating real-time medication authenticity verification and decentralizing governance. The blockchain network verifies every transaction across several nodes, guaranteeing that fake medications cannot be introduced covertly.

2.2.3 Challenges in Adoption

Blockchain has issues with scalability, integration, and regulatory compliance even while it increases transparency and reduces fraud. Blockchain networks can become less efficient due to high transaction volumes. Blockchain integration is difficult and necessitates major changes to current centralized pharmaceutical systems. Furthermore, different nations have different regulatory needs, which makes it challenging to adopt universally and necessitates the use of standardized rules for efficient execution.

2.3 Blockchain in Pharmaceutical Logistics and Inventory Management

2.3.1 Improving Supply Chain Efficiency

Several middlemen are involved in pharmaceutical logistics, which frequently results in inefficiencies, delays, and poor inventory management. Chen et al. (2023) investigated how blockchain may improve inventory monitoring and logistics. They discovered that timely medicine movement reports guarantee effective distribution, cut down on delays, and avoid stock shortages.

2.3.2 Overcoming Inventory Mismanagement

The manual inventory tracking used in traditional supply chains is frequently prone to mistakes, delays, and inefficiencies. Blockchain-based solutions improve inventory management by reducing inconsistencies, guaranteeing data consistency, and automating transaction recording. The real-time tracking of medication transportation by stakeholders using a transparent and safe ledger lowers the risk of fraud and boosts supply chain effectiveness overall.

2.3.3 Implementation Barriers

Blockchain adoption is fraught with difficulties despite its benefits. Chen et al. (2023) pointed out that as installing blockchain infrastructure necessitates a significant investment, the high implementation costs represent a significant obstacle. The shift to blockchain-based solutions is also challenging as many industry stakeholders are reluctant to adapt since they are not experienced with decentralised systems.

2.4 Authentication Mechanisms Using Blockchain

2.4.1 QR Code-Based Anti-Counterfeit Systems

Blockchain-based authentication systems are essential for guaranteeing the genuineness of pharmaceuticals and eliminating counterfeiting. Each medication packaging is given a unique QR code that is safely connected to blockchain records under a technique that was proposed by Patel et al. (2024). Important information, including the drug's origin, batch number, production date, and whole transaction history, may be confirmed by stakeholders by scanning the QR code. By increasing transparency and offering real-time verification, this approach lowers the possibility of fake medications getting into the supply chain.

2.4.2 Security Vulnerabilities in QR Codes

Although QR codes greatly improve traceability and verification in the pharmaceutical supply chain, security risks still exist. According to Patel et al. (2024), some flaws allow hackers to copy QR codes or alter the scanning procedure to get over security measures, which might result in the sale of fake medications. These security flaws show that to improve the overall security of blockchain-based authentication systems, further safeguards are required, including multi-layer authentication, dynamic QR codes, or encryption approaches.

2.4.3 Strengthening Authentication with Digital Signatures

Digital signature integration with QR codes was suggested by Nguyen et al. (2023) as a solution to QR code vulnerabilities. This makes it practically hard to counterfeit QR codes as they cannot be changed without cryptographic verification. However, the adoption of this system may be constrained by the expensive computing resources and robust regulatory backing needed for its implementation.

2.5 Enhancing Scalability and Security with Multi-Blockchain Systems

2.5.1 Multi-Blockchain Architectures for Scalability

The scalability of blockchain technology is still a significant issue, particularly for large-scale pharmaceutical transactions. Multi-Med Chain, a multi-party blockchain system created by Kumar & Singh (2024) allow producers, distributors, and retailers to communicate with distinct but related blockchain records. This enhances access control and transaction processing speed.

2.5.2 Computational Overhead and Cost Challenges

According to Kumar & Singh (2024), multi-blockchain frameworks increase computational overhead, raising transaction costs and influencing processing speed, even though multi-MedChain improves scalability. For practical application, this efficiency vs. security trade-off needs to be resolved.

2.5.3 Cybersecurity Benefits of Decentralized Ledgers

Williams et al. (2021) investigated the potential of blockchain technology to thwart cyberattacks. The immutability and encryption of blockchain transactions greatly lower the possibility of data breaches. Performance constraints in extensive pharmaceutical supply chains, however, continue to be an issue.

2.6 Smart Contracts and Automated Verification

2.6.1 Eliminating Intermediaries with Smart Contracts

Smart contracts, which are self-executing blockchain-based contracts, have been shown by Garcia et al. (2022) to automate ownership transfers and drug verification. By doing this, middlemen are removed, transaction costs are decreased, and efficiency is increased.

2.6.2 Regulatory Challenges in Smart Contracts

Despite all of their advantages, smart contracts are not widely used in pharmaceutical supply chains due to substantial legal and regulatory obstacles. The enforceability of blockchain-based contracts is unknown since many jurisdictions do not yet recognise them as legally enforceable agreements. Adoption is slowed by this ambiguity in the law, as pharmaceutical firms would be reluctant to use smart contracts without regulatory clearance. Policymakers must create precise legal frameworks that facilitate the incorporation of blockchain-based contracts into supply chain management to address these issues.

2.6.3 Privacy Concerns in Blockchain Networks

Although blockchain guarantees transparency, data privacy is an issue. The dangers of keeping private patient and supplier data on blockchain networks were emphasised by Adams et al. (2024). They proposed encrypted ledgers and zero-knowledge proofs as ways to improve privacy.

2.7 Blockchain-Based Secure and Transparent Drug Supply Chains

2.7.1 Improving Consumer Trust with Traceability

It can be difficult for consumers to confirm the legitimacy of medications before buying them, which raises the possibility of using fake medications. This problem was solved by Brown & White (2024), who created a blockchain-encrypted supply chain that improves traceability at every turn. Their solution makes sure that the provenance, production information, and transaction history of every medication are safely stored on an unchangeable blockchain ledger. Customers may quickly obtain validated information about the medication by scanning a unique identification, such as a QR code, guaranteeing its authenticity before use. This strategy boosts customer trust in pharmaceutical items while also increasing openness.

2.7.2 Challenges in Transitioning from Traditional Systems

Blockchain technology adoption in pharmaceutical supply chains is hampered by its high initial investment costs despite its many benefits. Significant financial resources are needed for workforce training, infrastructure development, and interaction with current systems when implementing a blockchain-based system. Because of these costs, many pharmaceutical firms are reluctant to move away from traditional supply chains, particularly small and mid-sized businesses. Widespread adoption is further hampered by operational limitations, including adjusting to decentralised systems, maintaining regulatory compliance, and resolving technological difficulties. More businesses may adopt blockchain for safe and open supply chain management if these issues are resolved with affordable fixes and government incentives.

CHAPTER 3

RESEARCH GAPS OF EXISTING METHODS

Sl. No.	Paper Title	Authors	Year	Limitations (Research Gaps)
1	Distributed Ledger Technologies in Healthcare	Adams et al.	2024	Privacy concerns
2	Secure and Transparent Drug Supply Chain Using Blockchain	Brown & White	2024	High initial investment
3	Protected QR Code-Based Anti-Counterfeit System	Patel et al.	2024	QR code encryption vulnerabilities
4	Multi-MedChain: Multi-Blockchain System	Kumar & Singh	2024	Computational overhead
5	Blockchain Technology in Pharmaceutical Supply Chain Management	Smith et al.	2023	Scalability and integration challenges
6	Blockchain Applications in the Pharmaceutical Industry	Johnson & Lee	2023	Regulatory compliance issues
7	Digitalization Enhancement in Pharmaceutical Supply Network	Chen et al.	2023	Adoption barriers

8	Authenticating Medications with QR-Codes	Nguyen et al.	2023	Digital signature infrastructure dependency
9	Blockchain-Based Drug Authentication System	Thompson & Wright	2023	High implementation cost
10	AI and Blockchain for Medicine Authentication	Lewis et al.	2023	Complex integration with AI
11	Smart Contracts for Secure Pharmaceutical Supply Chains	Garcia et al.	2022	Legal and regulatory barriers
12	Security of Blockchain-Based Systems	Williams et al.	2021	Performance concerns

Table 3.1 Research Gaps of Existing Methods

CHAPTER 4

PROPOSED METHODOLOGY

The proposed approach for placing in place a pharmaceutical supply chain system with blockchain capabilities for medication authentication and anti-counterfeiting. The methodology's main goal is to improve supply chain efficiency, security, and transparency by combining blockchain, smart contracts, artificial intelligence, and real-time tracking systems.

4.1 Requirement Analysis

Objective: Ensure safe monitoring, authentication, and transparency in the pharmaceutical supply chain by creating a blockchain-integrated solution to stop fake medications.

Activities

- Apply blockchain technology to build a decentralized ledger with unchangeable transaction records.
- Automate medication ownership transfers and verification with smart contracts.
- For real-time authentication, each medication pack has a unique QR code.
- Incorporate anomaly detection powered by AI to spot questionable transactions and stop counterfeiting.
- Give producers, distributors, retailers, and customers access to real-time tracking.
- Use distributed databases and cloud-based load balancing to guarantee scalability.
- Use access control and blockchain encryption to improve security and privacy.

Technical Stack

- HTML5, CSS3, JavaScript, React.js for an intuitive user interface.
- Backend Node.js, Express.js for server-side logic.
- Database MongoDB for storing user credentials, chats, and uploaded evidence.

4.2 Smart Contract Implementation

Objective: To improve security and efficiency, use self-executing smart contracts to automate ownership transfers and authentication.

Activities

- Create smart contracts that implement preset guidelines for the verification of medications.
- At every point of the supply chain—manufacturer, distributor, retailer, and consumer—automate ownership transfers.

4.3 QR Code Authentication

Objective: Improve the verification of medications by connecting blockchain transaction data to distinct QR codes, which makes authentication simple and safe.

Activities

- Create a distinct QR code with product data, manufacturer details, and transaction history for every batch of medications.
- Create a QR code scanning app that works on mobile devices for instantaneous verification.
- To prevent counterfeiting and copying, make sure QR codes include tamper-resistant encryption.
- Give customers immediate access to blockchain records after scanning them to promote transparency.

Supply chain security is improved by AI-based anomaly detection, which spots questionable activity and stops the spread of fake medications. In order to identify irregularities, analyse transaction trends, and send out real-time notifications for unauthorised changes, an AI model is developed. In order to provide proactive risk management, machine learning algorithms assist in anticipating and reducing fraudulent activity. Artificial intelligence models are updated often to reflect new risks in order to remain successful. Cloud-based architectures that provide smooth extension and high availability also guarantee system scalability and security. Large transaction volumes are handled effectively using distributed databases, and sensitive pharmaceutical data is protected by end-to-end encryption. System integrity is further reinforced, and any vulnerabilities are avoided by routine security audits.

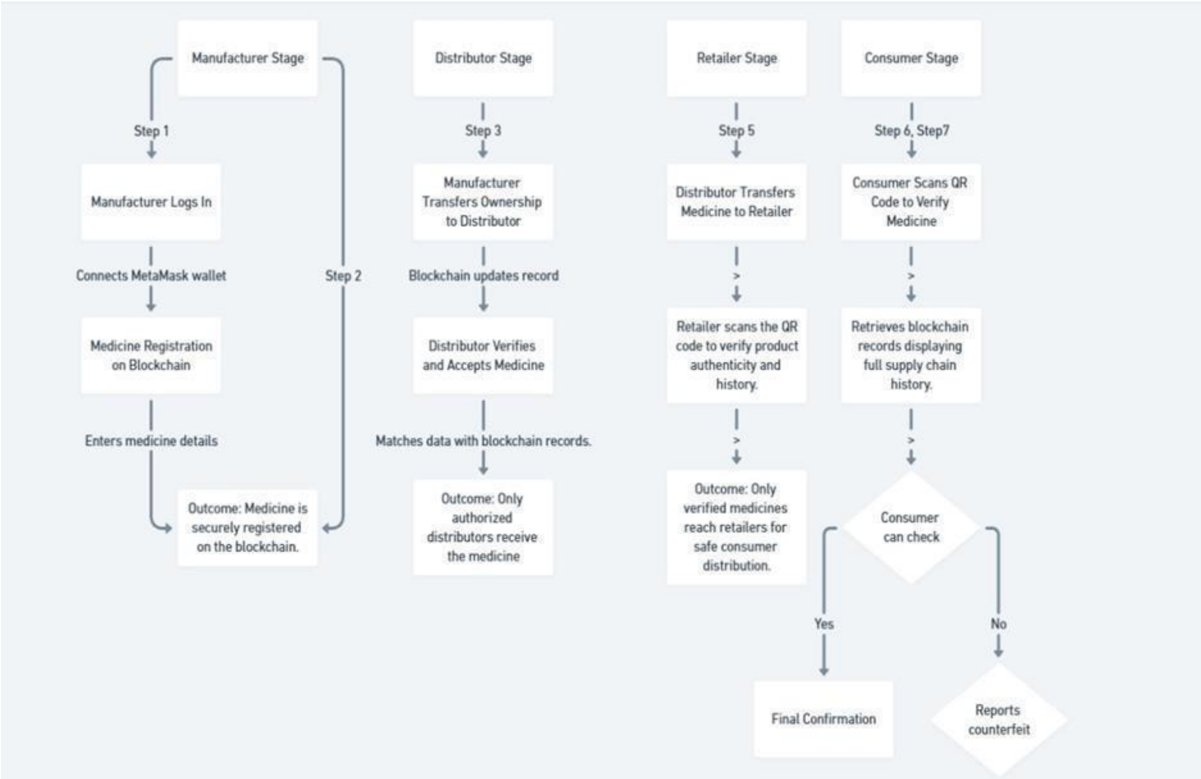

Fig 4.1 Mind Map

A blockchain-based pharmaceutical supply chain that prevents counterfeiting and guarantees medicine authenticity is illustrated in the flowchart. The Manufacturer Stage involves the manufacturer logging in, connecting their MetaMask wallet, registering medicine details on the blockchain, and securely storing transaction records. The Distributor Stage involves the transfer of ownership from the manufacturer to the distributor, who verifies and accepts the medicine by comparing it with blockchain data, ensuring that only authorised distributors handle the product.

The distributor gives the medication to the retailer at the Retailer Stage, who scans a QR code to confirm its legitimacy and background. Only validated medications are sent to patients. The customer accesses the blockchain data showing the whole supply chain history in the customer Stage by scanning the QR code. Transparency and security in the pharmaceutical supply chain are ensured if the details are validated; if not, the transaction is confirmed, and counterfeit medication is notified.

CHAPTER 5
OBJECTIVES

5.1 Develop a Decentralized, Transparent, and Tamper-Proof Medicine Tracking System:

The objective is to use blockchain technology to build an unchangeable, safe system for monitoring medications across the supply chain. By ensuring that no one party may change or modify records, a decentralized ledger promotes transparency and guards against fraud. For all parties concerned—manufacturers, distributors, retailers, and customers—this system offers a trustworthy source of information.

5.2 Enable Manufacturers, Distributors, Retailers, and Consumers to Verify Medicine Authenticity:

Real-time verification methods combined with blockchain technology allow all supply chain participants to confirm the legitimacy of medications. On the blockchain, producers may register medications, and distributors and merchants can verify the authenticity of supplies they have received. Customers may verify a product's origin and supply chain history by scanning a QR code, assuring they are buying authentic medication.

5.3 Reduce Counterfeit Drugs in the Market Through Blockchain's Immutability:

Blockchain technology can greatly reduce the major health concerns associated with counterfeit medications. False entries or fraudulent updates are almost impossible since blockchain records are unchangeable. From production to customer purchase, every transaction is continuously documented to guard against illegal changes and guarantee that only validated medications are released into the market.

5.4 Provide Real-Time Tracking and Monitoring for Regulators and Stakeholders:

Real-time data is necessary for regulatory bodies and supply chain participants to efficiently monitor the distribution of medications. Continuous tracking of medications from manufacture to end-user usage is made possible by the suggested method. This aids authorities in spotting anomalies, stopping the unlawful distribution of drugs, and reacting promptly to possible dangers or supply chain infractions.

5.5 Implement a User-Friendly QR Code-Based Verification System:

A QR code-based approach will be used to enable pharmaceutical authentications for all users, including customers. A distinct QR code connected to blockchain data will be included on every medication box. Information regarding the medication's origin, batch number, expiration date, and complete supply chain history may be instantaneously retrieved by scanning the QR code with a smartphone or other digital device. This guarantees usability and encourages broad usage of the verification system.

CHAPTER 6

SYSTEM DESIGN & IMPLEMENTATION

6.1 System Design

The blockchain-based medication monitoring system stores unchangeable transaction data, guaranteeing authenticity, security, and transparency. Drug manufacturers register their products, and ownership transfers are automated using smart contracts. A distinct QR code is included with every delivery to enable stakeholders to verify authenticity. While cloud-based architecture guarantees scalability, anomaly detection driven by AI improves security. End-to- end encryption safeguards private information and gives authorities real-time surveillance to successfully fight fake medications.

6.1.1 Architecture Overview

Smart contracts streamline ownership transfers, and producers register medications on the system's decentralized blockchain database. Transactions are stored in a secure database, and abnormalities are identified using AI. Scalability is guaranteed via cloud infrastructure, enabling real-time tracking. Using React.js UI and QR code authentication, users validate medications. Data is protected by end-to-end encryption, and regulatory integration is made possible by APIs, guaranteeing transparency and preventing counterfeiting.

6.1.2 Data Flow Diagram

The system operates in distinct phases, users interact with the chatbot interface, reporting incidents, or seeking guidance. Inputs are processed by the backend, using Natural Language Processing **(NLP) algorithms** to interpret user queries and respond empathetically. Storage & Retrieval Incident details, evidence, and user data are securely stored in the MongoDB database, with encryption applied. Reporting Collected evidence and reports are anonymized and securely forwarded to **cyber-crime authorities.**

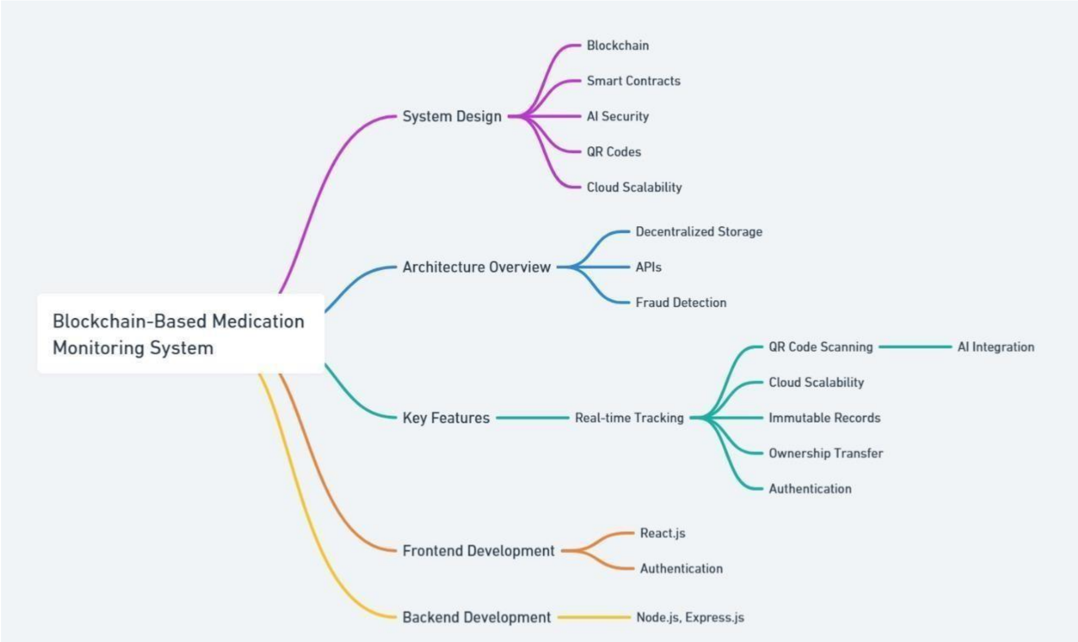

Fig 6.1 System Design

6.1.3 Key Features

The system uses **smart contracts**, **decentralized ledger**, and **QR code** authentication to guarantee safe medication tracking. Real-time tracking improves efficiency, while **AI detection** detects fake medications. Secure reporting is made possible by regulatory integration, accountability is guaranteed by audit logging, and data is protected by end-to-end encryption.

6.1.4 Frontend Development

The front end, which has been built with HTML5, Tailwind CSS, React.js, and JavaScript, is intended to be simple to use and intuitive. Manufacturers, distributors, merchants, and consumers may easily navigate it to confirm the legitimacy of medications. The interface facilitates secure user authentication, real-time tracking, and QR code scanning. Responsive design improves usability by guaranteeing accessibility on a range of devices.

6.1.5 Backend Development

Built using Node.js and Express.js, the backend controls APIs for authentication, ownership transfers, and medication registration. It integrates smart contracts for audit recording and verification, and guarantees secure data processing, encryption, and smooth blockchain interaction.

6.1.6 Database Management

Transaction records, user credentials, and medication details are stored in the database, which is powered by MongoDB. For tamper-proof record-keeping, it supports immutable blockchain integration and guarantees effective data retrieval, scalability, and security*.

6.1.7 Testing and Debugging

System security and dependability are guaranteed via testing and debugging. While integration testing ensures that the front end, backend, and blockchain all work together seamlessly, unit testing validates individual components. Data protection is ensured via security testing, which finds flaws. System speed and user experience are improved by ongoing debugging and optimization.

6.2 Challenges and Solutions

The system has to deal with problems such user uptake, security risks, regulatory compliance, scalability, and integration complexity. Distributed databases and cloud-based load balancing are used to solve scalability. APIs and middleware make it possible to integrate legacy systems with ease. Regional conformity is ensured via regulatory flexibility. Fraud is prevented via cryptographic security and anomaly detection driven by AI. Last but not least, training courses and an easy-to-use interface facilitate stakeholders' seamless adoption of blockchain-based tracking.

CHAPTER 7

TIMELINE FOR EXECUTION OF PROJECT (GANTT CHART)

	Deployment Preparation & Documentation	Final Testing & Quality Assurance	Integration & Initial Testing	Development Phase 2 (Advanced Features)	Development Phase 1 (Backend & Frontend)	Design (UI/UX and Architecture)	Requirement Analysis & Planning
Start Date	15/May	21/Apr	22/Mar	17/Mar	22/Feb	31/Jan	29/Jan
Duration	7	7	7	14	14	14	7

Fig 7.1 Gantt Chart

CHAPTER 8

OUTCOMES

1. **Increased security and trust in pharmaceutical supply chains** blockchain ensures tamper-proof records, limiting unwanted changes and improving medication tracking's transparency.

2. **Reduction in counterfeit medicine circulation** technology ensures that only authentic items are delivered to customers by preventing counterfeit medications from entering the supply chain through constant drug authenticity verification**.**

3. **Enhanced regulatory compliance through smart contracts** by automating regulatory enforcement, smart contracts guarantee adherence to pharmaceutical regulations and minimize administrative control.

4. **Real-time tracking and verification** Through the system, stakeholders can monitor the flow of medications from production to distribution, guaranteeing accountability and prompt action in the event of inconsistencies.

5. **Improved stakeholder confidence in medicine authenticity** Consumers, pharmacists, and regulators may all have faith in the validity of medications with an easily available verification system, boosting supply chain trust in general.

6. **Data integrity and transparency** complete transparency is ensured by immutable blockchain records, which give stakeholders unaltered access to verifiable data.

7. **Greater efficiency in supply chain management** in pharmaceutical delivery, automated tracking and verification reduce delays and inefficiencies by streamlining operations**.**

8. **Improved patient safety** by ensuring that consumers only receive genuine medications, the health risks linked with counterfeit medications are decreased

CHAPTER 9
RESULTS AND DISCUSSIONS

9.1 Results

The process reduced the number of fake medications, enhanced confidence, and strengthened supply chain security. Blockchain improved efficiency and patient safety by ensuring transparency, compliance, and smooth verification.

9.1.1 Performance Metrics

Data integrity, scalability, and transaction speed were used to assess the process's performance. Blockchain guarantees low processing latency and safe, unchangeable records. Verification in real time increased productivity and user confidence.

9.1.2 Security Achievements

Data manipulation is prevented by blockchain immutability and end-to-end encryption. Transactions are safe and transparent, thanks to smart contracts. Frequent security audits improve protection and reduce vulnerabilities.

9.1.3 Community Engagement

Campaigns to raise awareness inform stakeholders about the dangers of counterfeit drugs. Participation in medication verification is encouraged by user-friendly interfaces. Working together with authorities and medical experts increases uptake and trust.

9.2 Discussion

9.2.1 Enhanced Security and Transparency

Blockchain ensures a decentralised, tamper-proof ledger that safely logs each transaction, avoiding unwanted changes and lowering the risk of fraud in the pharmaceutical supply chain.

9.2.2 Challenges in Implementation

Blockchain implementation in pharmaceutical supply chains is fraught with difficulties, including regulatory compliance, high prices, and interoperability with traditional systems. Concerns about scalability, opposition from stakeholders, and striking a balance between data

9.2.3 Counterfeit Drug Prevention

The technology makes sure that only genuine medications reach customers by providing real-time authentication and immutable tracking, which drastically lowers the circulation of fake medications.

9.2.4 Future Implications

Blockchain technology in the pharmaceutical industry holds potential for increased automation, efficiency, and fraud prevention in the future. Global supply chains might be completely transformed by widespread use, guaranteeing safer and more transparent medicine distribution.

9.3 Limitations

Blockchain implementation encounters challenges such as integration complexities with existing systems and regulatory uncertainties. Additionally, ensuring data privacy while maintaining transparency remains a critical limitation.

9.4 Recommendations

Increasing the scalability of the blockchain can boost transaction volume efficiency. Enhancing security protocols will provide improved defense against online attacks. Facilitating cooperation among interested parties can lead to more seamless adoption and execution.

CHAPTER 10
CONCLUSION

10.1 Overview of the Project Outcomes

The project uses blockchain technology to improve pharmaceutical supply chains' security and transparency. Tamper-proof documentation aids in stopping the spread of fake medications. Manufacturers, distributors, retailers, and customers may all confirm authenticity via real-time tracking. Verification procedures are streamlined, and compliance is automated via smart contracts. With a transparent and unchangeable ledger, stakeholder trust increases. Customers can easily and securely verify their accounts with QR code authentication. Regulatory bodies can monitor and audit more effectively. All things considered, the strategy improves honesty and confidence in the delivery of pharmaceuticals.

10.2 Addressing the Problem of Counterfeit

By ensuring transparent tracking and verification at every stage, the project addresses the problem of counterfeit medications. Because blockchain records guard against data alteration, counterfeit medications have a harder time getting into the supply chain. Customers and stakeholders can rapidly confirm authenticity with QR code-based authentication. By automating compliance checks, smart contracts lower fraud and human mistakes. Authorities can swiftly identify and get rid of fake medications thanks to real-time surveillance. Security is improved by flagging questionable activity with the integration of AI. When taken as a whole, these actions increase public safety and foster confidence.

10.3 Challenges Encountered

Due to interconnection problems, integrating blockchain with current pharmaceutical infrastructures presented challenges. To ensure scalability while preserving transaction efficiency, protocol optimization was necessary. Widespread adoption was made more difficult by regional variations in regulatory compliance. Decentralized technology adoption was hampered by opposition from stakeholders who were not familiar with them. Data security and transparency presented new challenges that needed constant improvement and flexible solutions.

10.4 Future Enhancements

Improving interoperability with current healthcare infrastructures for smooth adoption is one of the next improvements. Increasing the strength of data encryption methods will improve privacy and security. User involvement will increase with the expansion of accessibility through multilingual support and mobile applications. Adding decentralized identity management can improve authentication and trust even more.

10.5 Broader Implications

By ensuring product authenticity and reducing fraud, this strategy increases consumer trust. Regulatory organizations are better equipped to monitor and enforce compliance. Global supply chains may become more secure, transparent, and efficient by using these strategies in more industries.

10.6 Final Thoughts

By strengthening security and transparency, this strategy lowers supply chain fraud. It ensures authenticity and adherence to regulations, which cultivates confidence among stakeholders. Using sophisticated verification techniques reduces risks and increases efficiency. Adoption will increase, and performance will be further optimized with ongoing enhancements. Expanded use has the potential to transform authentication and tracking procedures. All things considered, it opens the door to a more dependable and safer ecosystem.

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APPENDIX-A

PSEUDOCODE

1. Initialize backend

```
mkdir backend
cd backend
npm init -y
Node Server.js
```

2. Environment Variables (.env in backend folder):

```
PORT=5000
MONGODB_URI=mongodb://localhost:5000
JWT_SECRET=your_secret_key
```

3. Server Code (server.js):

```
const express = require("express");
const mongoose =
require("mongoose");
const bcrypt = require("bcrypt");
const jwt = require("jsonwebtoken");
const cors = require("cors");
const path = require("path");
const apiRoutes =
require("./routes/api");

const app = express();
const PORT = process.env.PORT ||
5000;

// Middleware
app.use(cors());
app.use(express.json({ limit: "50mb"
}));
app.use(express.urlencoded({
extended: true, limit: "50mb" }));

app.use(express.static(path.join(_dirn
ame, "public")));

// Connect to MongoDB
mongoose.connect("mongodb://localh
ost:27017/medicineVerification", {});

const db = mongoose.connection;
```

```
db.on("error",
console.error.bind(console,
"MongoDB connection error:"));
db.once("open", () =>
console.log("Connected to
MongoDB"));

// User Schema & Model
const userSchema = new
mongoose.Schema({
name: String,
  email: String,
  password: String,
  phone: String,
  address: String,
  license: String,
  gst: String,
  regId: String,
});

const User = mongoose.model("User",
userSchema);

// Register API
app.post("/api/Oneregister", async
(req, res) => {
  const { name, email, password,
phone, address, license, gst, regId } =
req.body;

  const hashedPassword = await
bcrypt.hash(password, 10);

  const newUser = new User({ name,
email, password: hashedPassword,
phone, address, license, gst, regId });

  await newUser.save();
  res.json({ success: true, message:
"User registered successfully!" });
});

// Login API
app.post("/api/login", async (req, res)
=> {
  const { email, password } = req.body;
const user = await User.findOne({
email });
```

```
  if (!user || !(await
bcrypt.compare(password,
user.password))) {
    return res.json({ success: false,
message: "Invalid credentials" });
  }

  const token = jwt.sign({ userId:
user._id }, "SECRET_KEY", {
expiresIn: "1h" });
  res.json({ success: true, token });
});

// API Routes
app.use("/api", apiRoutes);

// Serve HTML pages
app.get("/", (req, res) => {
  res.sendFile(path.join(_dirname,
"views", "Mainindex.html"));
});


app.get("/register", (req, res) => {
res.sendFile(path.join(_dirname,
"views", "register.html"));
});
app.get("/manufacturer-login", (req,
res)     =>     {
res.sendFile(path.join(_dirname,
"views", "manufacturer-login.html"));
});

app.get("/verify", (req, res) => {
res.sendFile(path.join(__dirname,
"views", "verify.html"));
});

app.get("/track", (req, res) => {
res.sendFile(path.join(_dirname,
"views", "track.html"));
});

// Start server
app.listen(PORT, () => {
  console.log(`Server running on port
${PORT}`);
});
```

4. Initialize frontend

```
npx create-react-app frontend
cd frontend
npm install axios react-router-dom
```

5. Implement Components

APP.JS

```
import React from 'react';
import { BrowserRouter as Router, Route, Routes } from 'react-router-dom';
import Register from './components/Register';
import Login from './components/Login';
import Chatbot from './components/Chatbot';
import './App.css';

function App() {
    return (
        <Router>
            <div className="app-container">
                <Routes>
                    <Route path="/register" element={<Register />} />
                    <Route path="/login" element={<Login />} />
                    <Route path="/chatbot" element={<Chatbot />} />
                </Routes>
            </div>
        </Router>
    );
}export default App;
```

INDEX.JS

```
import React from 'react';
import ReactDOM from 'react-dom';
import './index.css';
import App from './App';

ReactDOM.render(
  <React.StrictMode>
    <App />
  </React.StrictMode>,
  document.getElementById('root')
);
```

MEDERIFICATION.SOL

```
import // contracts/MedicineVerification.sol
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract MedicineVerification {
    struct Medicine {
        string manufacturer;
        string medicineName;
        string batchNo;
        string expiryDate;
        string manufacturedDate;
        bool isRegistered;
        bool isDelivered;
    }

    mapping(string => Medicine) public
medicines;
    string[] public medicineIds;

    event MedicineRegistered(string
batchId);
    event MedicineDelivered(string batchId);

    function registerMedicine(
        string memory batchId,
        string memory manufacturer,
        string memorymedicineName,
        string memory batchNo,
        string memory expiryDate,
        string memory manufacturedDate
    ) public {

require(!medicines[batchId].isRegistered,
"Medicine already registered");

        Medicine memorynewMedicine =
Medicine({
            manufacturer: manufacturer,
            medicineName: medicineName,
            batchNo: batchNo,
            expiryDate: expiryDate,
            manufacturedDate:
manufacturedDate,
            isRegistered: true,
```

```
        isDelivered: false
      });

      medicines[batchId] = newMedicine;
      medicineIds.push(batchId);

      emit MedicineRegistered(batchId);
    }

    function verifyMedicine(string memory
batchId) public view returns (


      string memory manufacturer,
      string memorymedicineName,
      string memory batchNo,
      string memory expiryDate,
      string memory manufacturedDate,
      bool isRegistered,
      bool isDelivered
    ) {
      Medicine memorymedicine =
medicines[batchId];
      return (
        medicine.manufacturer,
        medicine.medicineName,
        medicine.batchNo,
        medicine.expiryDate,
        medicine.manufacturedDate,
        medicine.isRegistered,
        medicine.isDelivered
      );
    }

    functionupdateDeliveryStatus(string
memory batchId) public {

require(medicines[batchId].isRegistered,
"Medicine not registered");
      medicines[batchId].isDelivered = true;
      emit MedicineDelivered(batchId);
    }

    functiongetAllMedicines() public view
returns (string[] memory) {
```

```
    return medicineIds;
  }
}
```

CODE SUMMARY :

1. The project is a web-based interface for a **blockchain-powered pharmaceutical supply chain**.
2. It ensures **medicine authentication** and detects **counterfeit drugs** using decentralized technology.
3. Users can log in based on roles: **Manufacturer**, **Distributor**, or **Consumer**.
4. Each role has a dedicated login card with unique colors and icons for better UX.
5. The interface is designed using **HTML and CSS** with responsive and modern styling.
6. A **full-screen background image** enhances the visual appearance.
7. A **MetaMask wallet integration** is included for blockchain connectivity.
8. Web3.js is linked to enable **smart contract interaction** in the backend.
9. The layout uses **Flexbox** for alignment and smooth transitions for interactivity.
10. The platform promotes **secure and transparent medicine tracking** from production to consumption

APPENDIX-B

SCREENSHOTS

Website main page

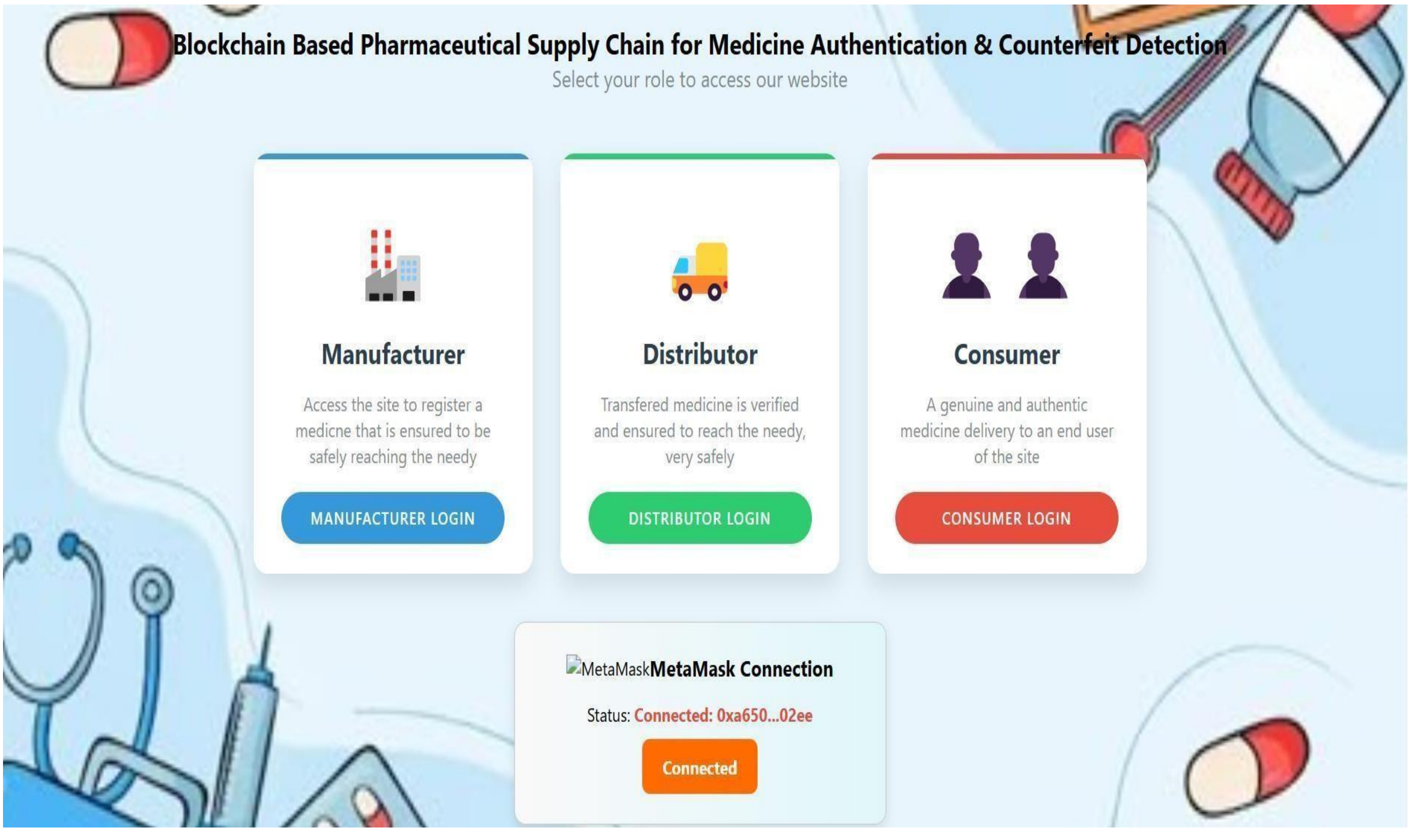

Fig A1.1 Main Page

Navigate to Sign Up section to Manufacture register yourself

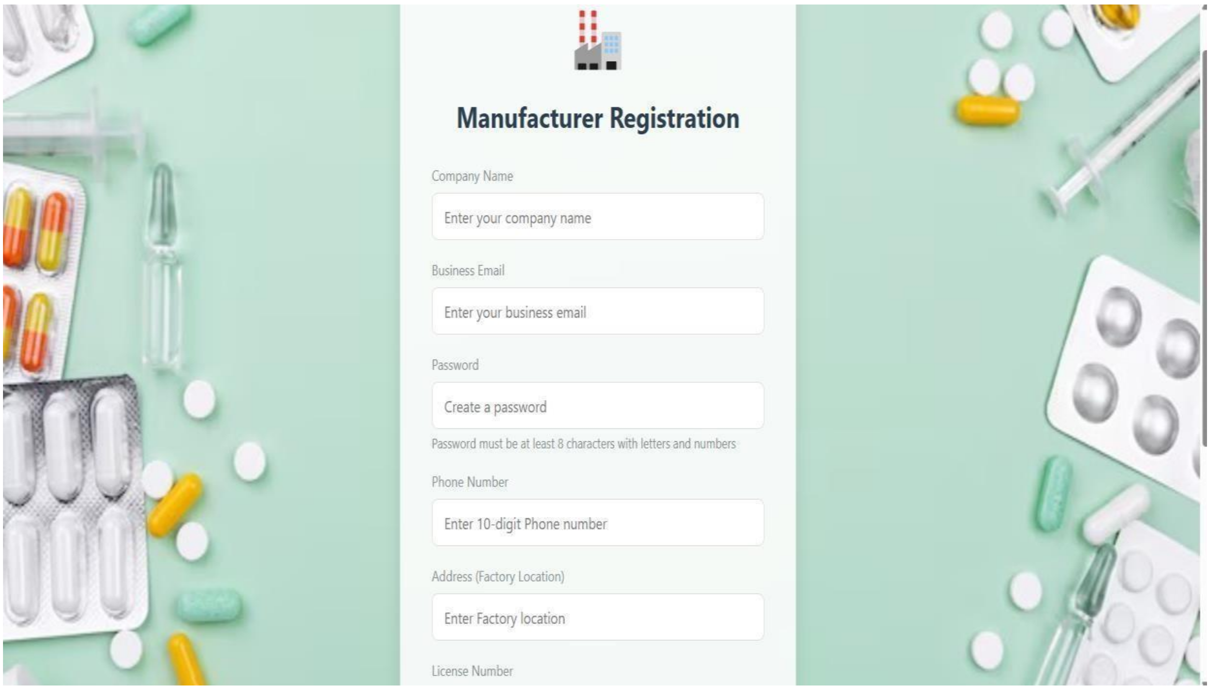

Fig A1.2 Manufacture Registration Page

Now we can continue to Manufacture Login Section directly

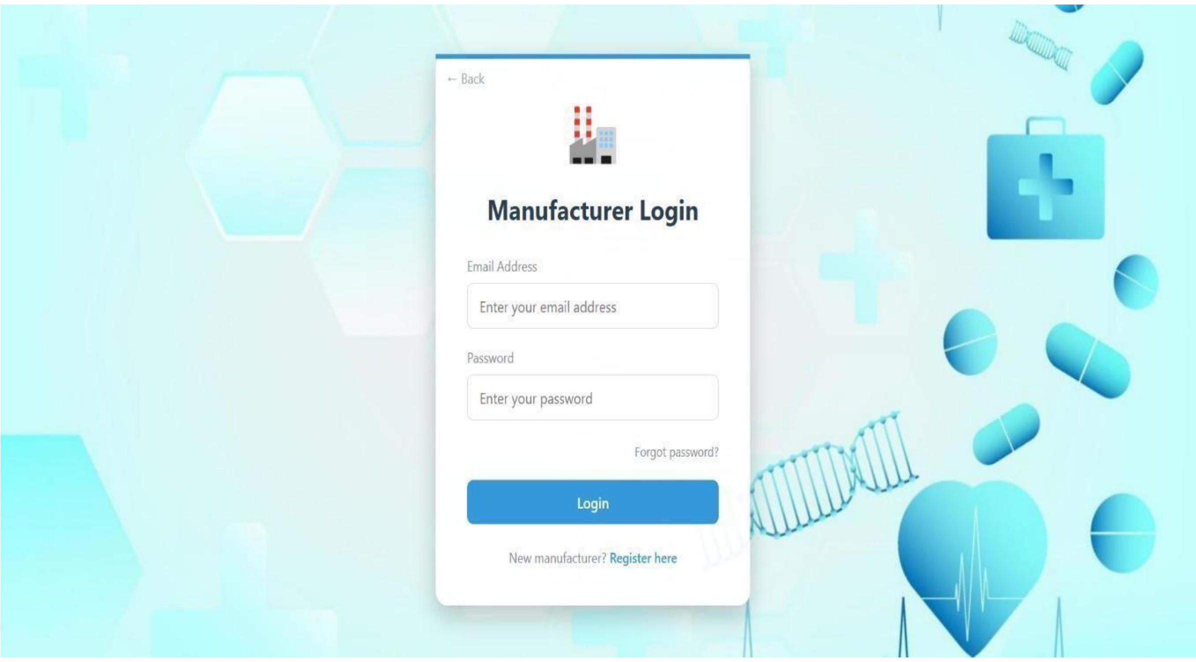

Fig A1.3 Manufacture Login page

Here we can come and observe Manufacture Dashboard having register medicine and track medicine

Fig A1.4 Manufacture Dashboard

We can enter our medicine details

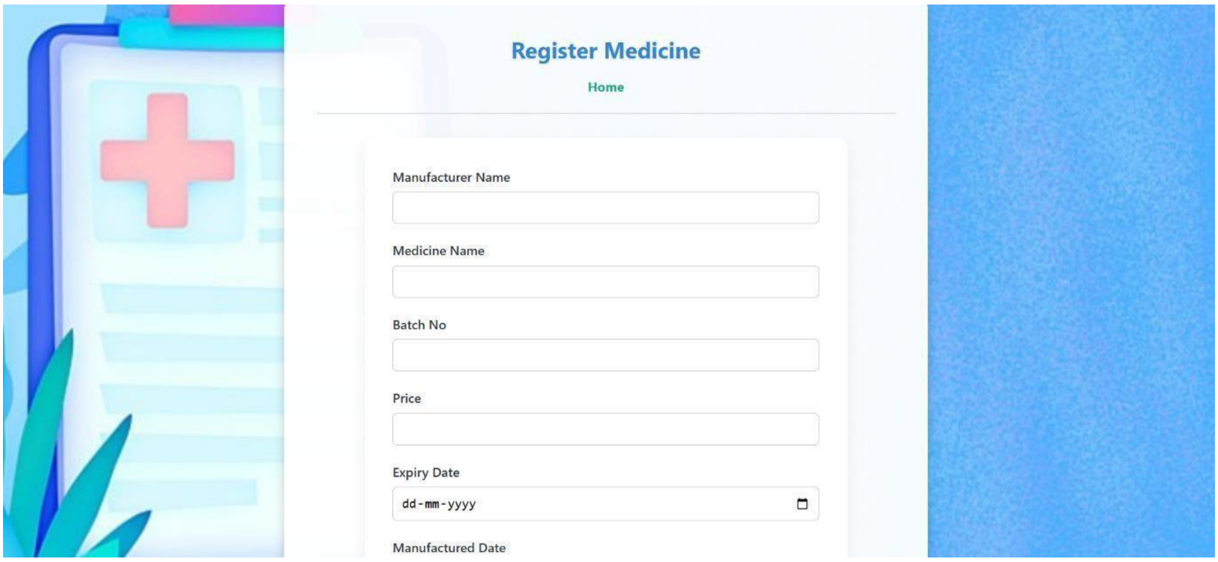

Fig A1.5 Register Medicine

Here we can track medicine

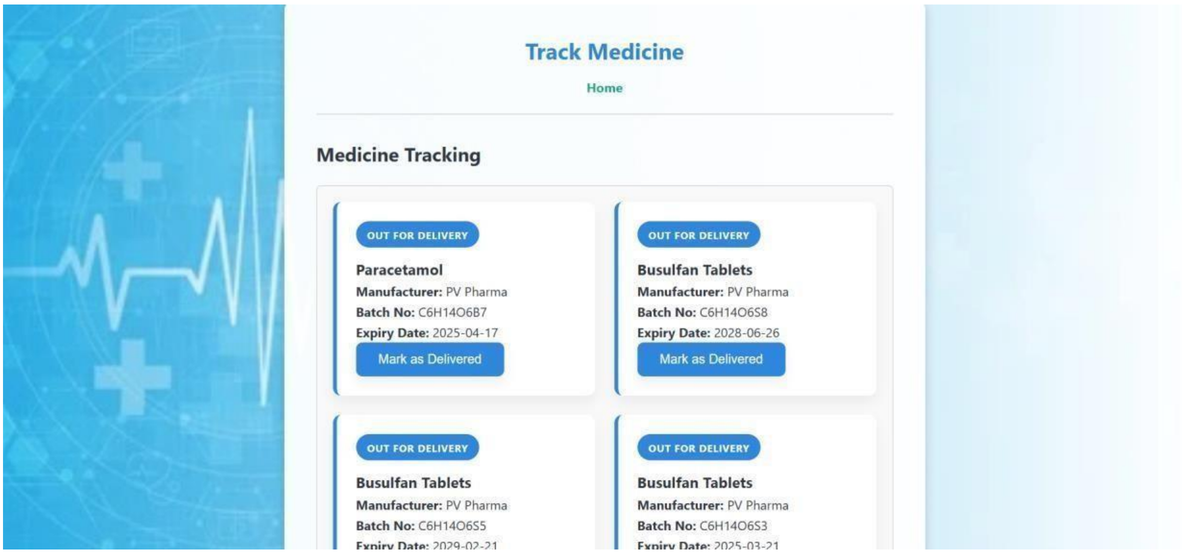

Fig A1.6 Medicine Tracking

Now we will proceed to distributor section

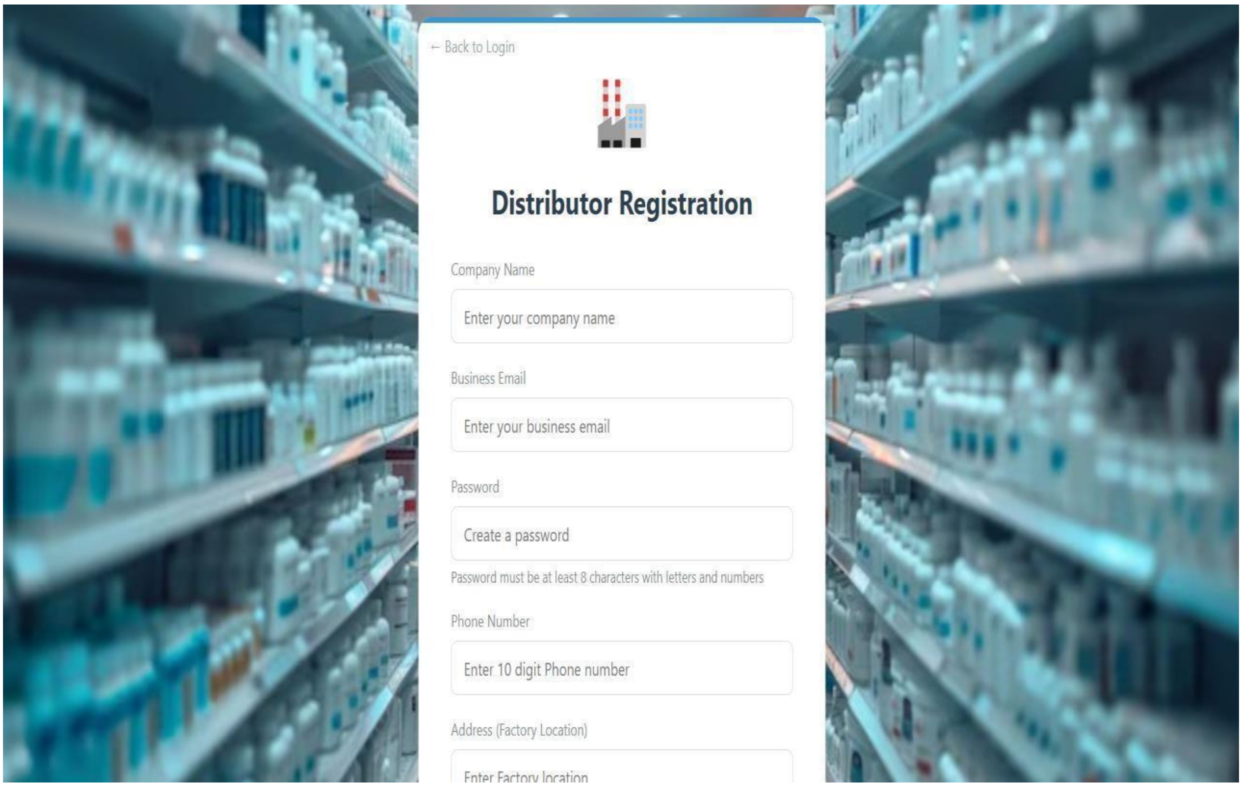

Fig A1.8 Distributor Registration

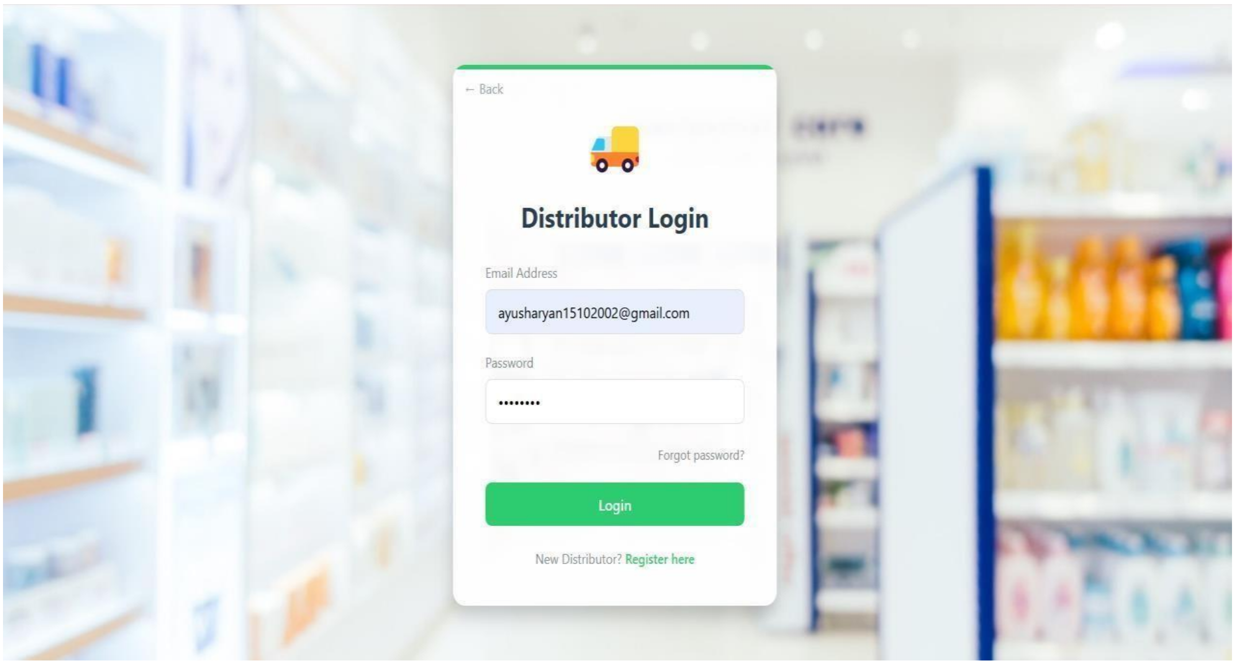

Fig A1.9 Distributor Login

Here Distributor Can Verify Medicine Details

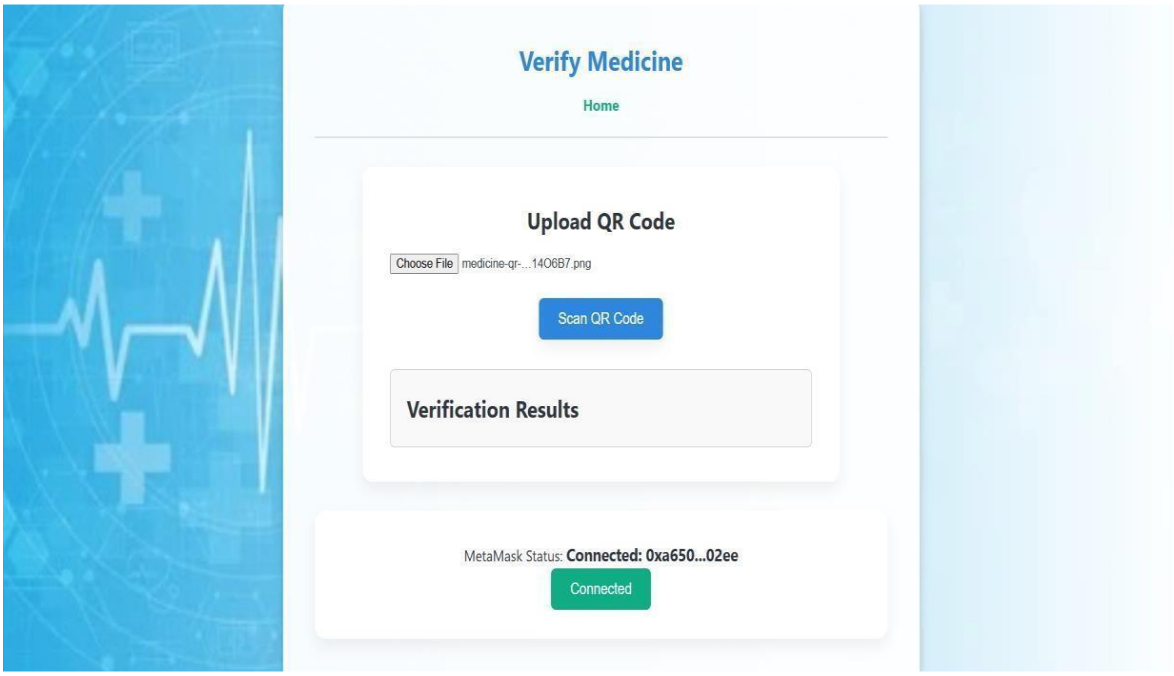

Fig A1.10 Verification Page

Now to consumer Side

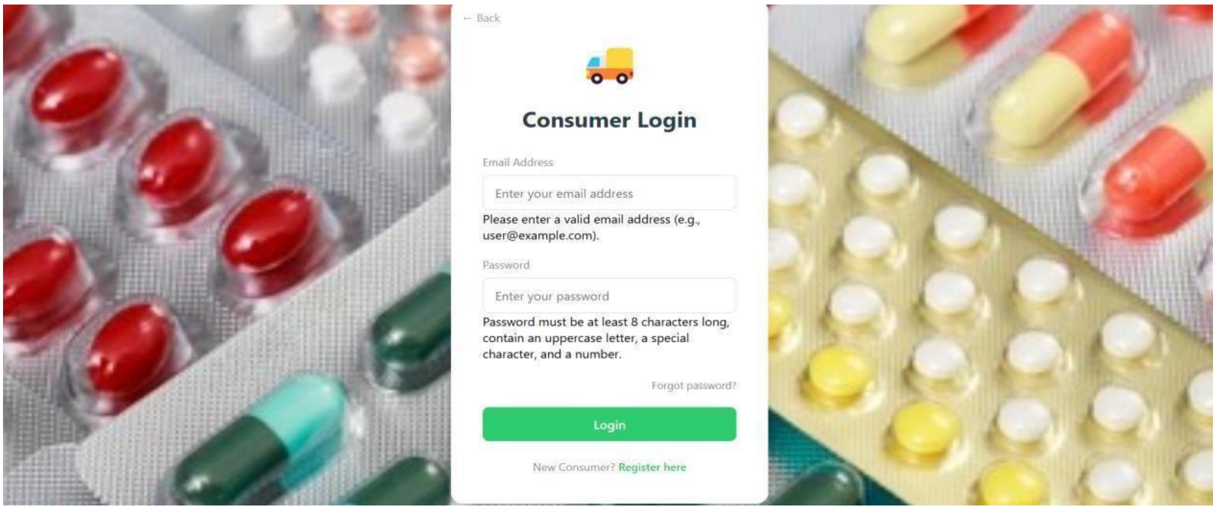

Fig A1.11 Consumer Login

Backend Section

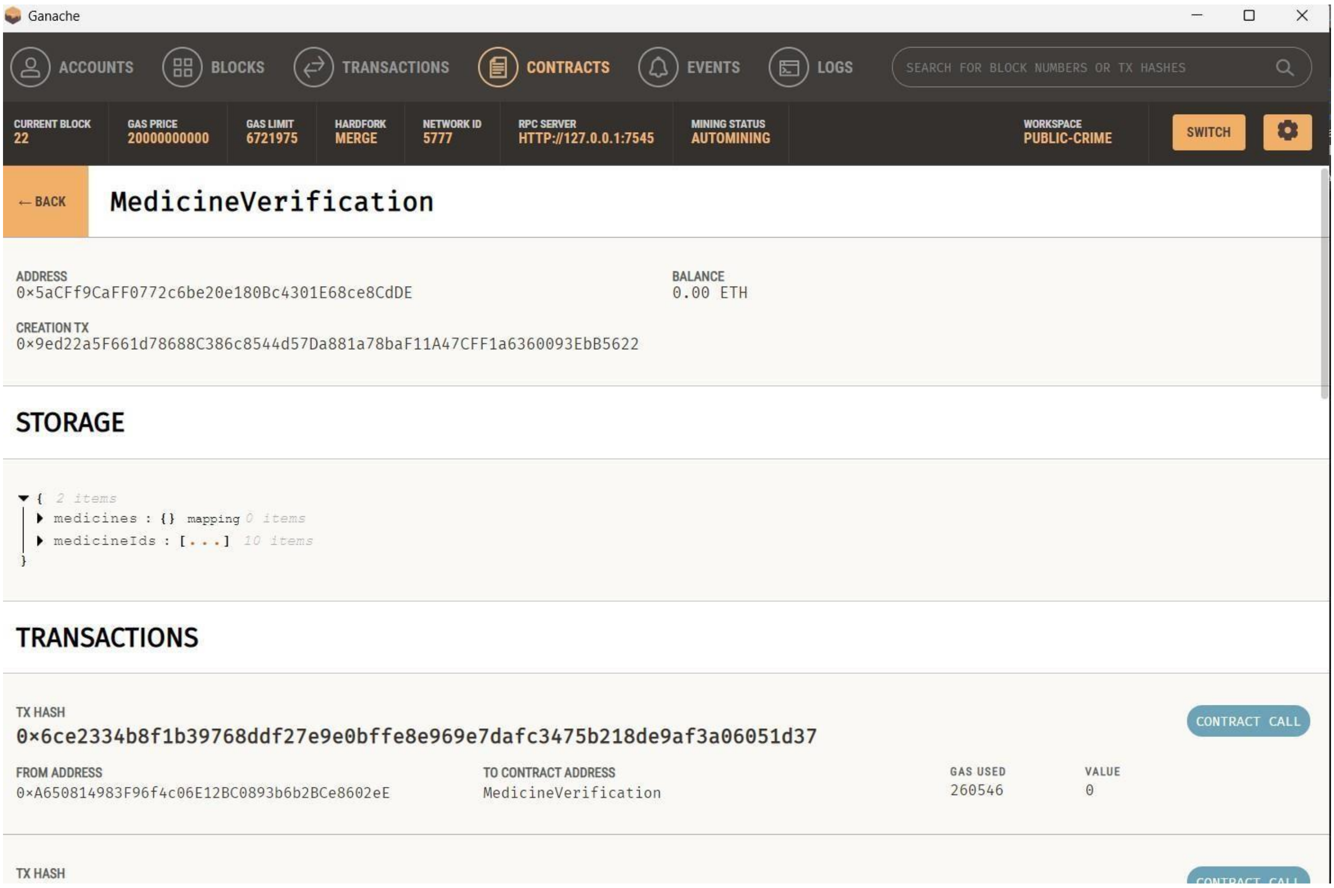

Fig A1.12 Ganache Backend

APPENDIX-C

ENCLOSURES

Plagiarism Report

ORIGINALITY REPORT

4%	2%	0%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

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2	Submitted to Swinburne University of Technology Student Paper	<1%
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5	Submitted to University of Portsmouth Student Paper	<1%
6	Submitted to Woxsen University Student Paper	<1%
7	stuartbramhall.wordpress.com Internet Source	<1%
8	arxiv.org Internet Source	<1%
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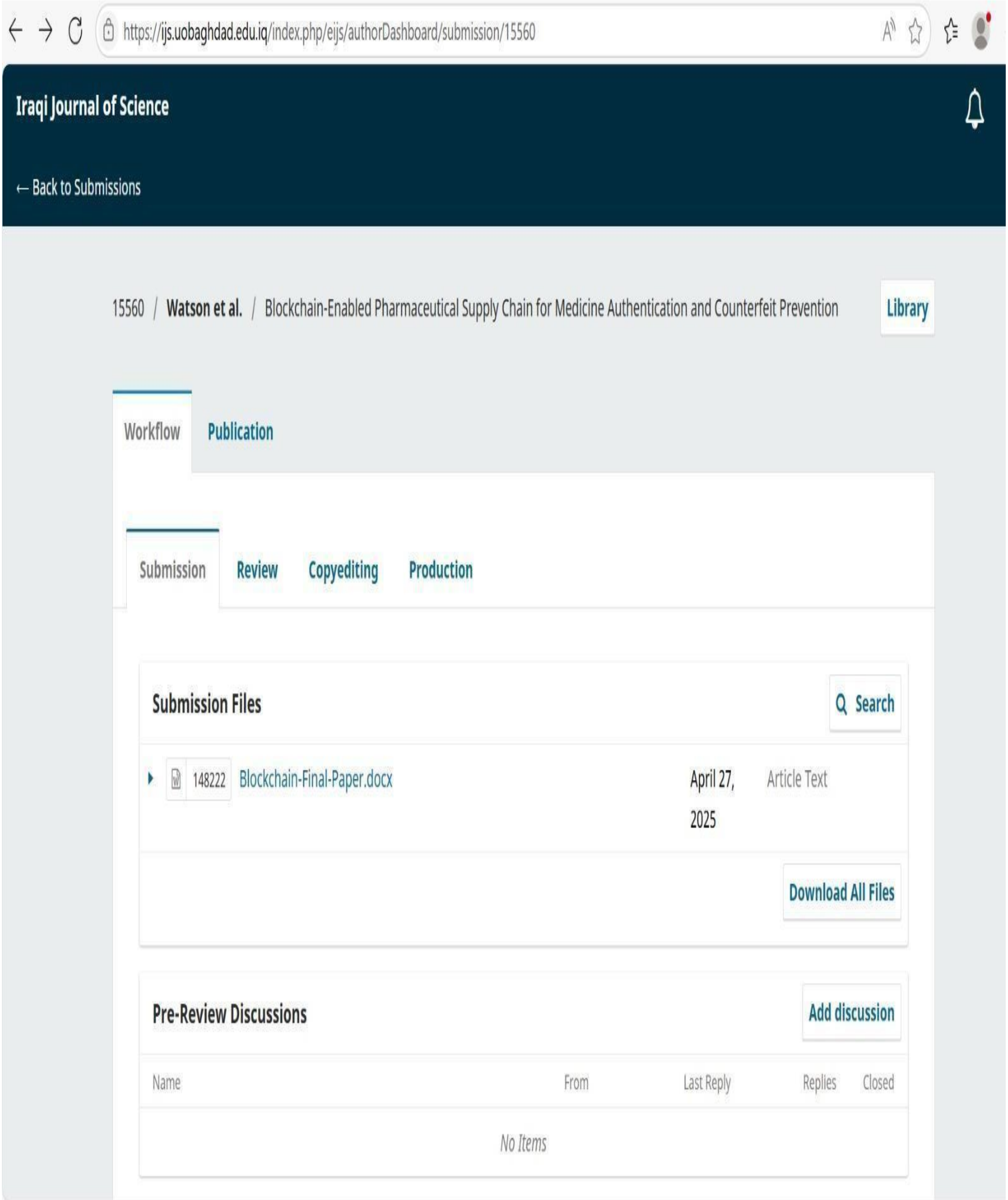
https://ijs.uobaghdad.edu.iq/index.php/eijs/authorDashboard/submission/15560
Iraqi Journal of Science
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15560 / Watson et al. / Blockchain-Enabled Pharmaceutical Supply Chain for Medicine Authentication and Counterfeit Prevention
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Submission Acknowledgement

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الباحث العزيز

يرجى تزويدنا بنسخة من وصل التسديد المالي خلال مدة (أسبوع) لكي نستطيع البدء بعملية التقييم للبحث رسوم النشر:

يجب على الباحثين العراقيين دفع مبلغ 50,000 دينار عراقي عند تقديم البحث للمجلة (غير قابلة للارجاع) وفي حالة قبوله للنشر يتوجب دفع 125,000 دينار آخرى في حالة كون البحث 12 صفحة او اقل وذلك لتغطية تكاليف النشر والاستلال. أما إذا كان البحث اكثر من 12 صفحة يدفع الباحث 2,500 دينار لكل صفحة إضافية.

اذا كان البحث يحتوي على صور او جداول ملونة فالباحث ملزم بدفع مبلغ 5,000 دينار عراقي عن كل صفحة تحوي على صورة او جدول ملون.

جميع البحوث المقبولة للنشر في المجلة العراقية للعلوم تخضع للتصحيح اللغوي باجور مقدارها (75,000) خمسة وسبعون الف ديناراً وذلك للوصول بمستوى اللغة الانكليزية للبحوث الى مستوى قياسي خالي من الاخطاء .

طرق دفع الرسوم:

توفر المجلة طريقتان لدفع الرسوم

يمكن الدفع المباشر بالحضور الى مقر المجلة العراقية للعلوم في بناية قسم الرياضيات وقسم علوم الحاسوب في كلية العلوم جامعة بغداد.

يمكن تسديد المبلغ عن طريق (زين كاش) على الرقم الخاص بالمجلة (07903375590). ولمزيد من التفاصيل يمكن الاتصال بسكرتارية المجلة على الرقم (07903375590) او (07700504040).

ملاحظة مهمة: في حالة ثبوت اي حالة تلاعب بهدف التحايل على برامج الاستلال فان الباحثين المشتركين بالبحث سيحرمون من النشر مستقبلا بالمجلة. وفي الوقت نفسه ستقوم المجلة بابلاغ جهة انتساب الباحثين بالموضوع بشكل رسمي ليتم اتخاذ الاجراء القانوني المناسب وحسب تعليمات وقوانين تلك الجهة.

مع التقدير

Sustainable Development Goals

Fig A3.1 SDG

The "Billy" chatbot aligns with three key United Nations Sustainable Development Goals (SDGs): SDG 3 (Good Health and Well-being), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 16 (Peace, Justice, and Strong Institutions).

SDG 3: Good Health and Well-being

The chatbot addresses mental health challenges from cyberbullying by offering immediate emotional support through **NLP-powered empathetic responses**. It reduces stigma, fosters resilience, and provides victims with a safe, anonymous space to share concerns, enhancing mental health outcomes.

SDG 9: Industry, Innovation, and Infrastructure

As a technological innovation, the chatbot leverages AI, NLP, and real-time frameworks to address cyberbullying. Its scalable design and data visualization tools provide actionable insights, showcasing how resilient infrastructure can support societal well-being.

SDG 16: Peace, Justice, and Strong Institutions

By enabling anonymous reporting and secure data handling, the chatbot promotes justice and accountability while protecting victim identities. Collaborating with cyber-crime authorities strengthens institutional responses, creating safer online space.