Letter to Editor Open Access

Criminal Activity and Environmental Impact as Cryptocurrency Concerns

Sara Tavakoligolpaygani [1*]

1. School of Computer Science and Engineering, University of New South Wales, Sydney, Australia.

Abstract

The surge of cryptocurrencies, such as Bitcoin, has raised concerns regarding their widespread adoption without adhering to standard. Unlike traditional currencies, they operate on a decentralized system called blockchain, allowing trustless transactions. Trustless transaction could facilitate their use in social and economic crimes. This letter examines methods to regulate and control the use of cryptocurrencies in social and economic crimes. Additionally, it investigates the environmental impact resulting from the mining process associated with these digital assets. Some strategies are proposed to substitute the current mining process with more environmentally sustainable alternatives.

Keywords Cryptocurrency Concerns, Criminal Activity, Environmental Impact

Introduction

As the use of Cryptocurrencies increases, concerns increase due to their association with their negative implications. Cryptocurrency is a type of digital currency that use blockchain technology to work on a peer-to-peer basis. The nature of the blockchain means that two persons can have a transaction without exitance of a third party even if they do not trust each other, [1]. Unlike traditional currencies, Cryptocurrencies are not controlled by a central authority such as a government or central bank. This leads to social and economic implications. Negative social implications of cryptocurrencies include their use in criminal activities, heightened cybercrime, potential exacerbation of wealth inequality, insufficient consumer protections, and the exclusion of individuals without access to technology or knowledge of using technology. These factors together could deepen the social disparities. Negative Economic Implications of Cryptocurrency include environmental impact, volatility, market manipulation and tax evasion, [2].

This letter tries to analyse two of the most important social and economic implications of cryptocurrencies: first, the role of cryptocurrency in social and economic criminal activity, and second, addressing their environmental impacts. After that strategies will be explored to address these two economic, social implications associated with cryptocurrency usage. The first approach targets the involvement of cryptocurrencies in social and economic crimes, while the second addresses the environmental impact of mining process.

Association of cryptocurrencies in social and economic crimes

As documented by Kethineni et al, digital currency has gained interest as a means of exchange among certain groups involved in social criminal activities, such as drug dealers and extortion. In addition, the vagueness surrounding this situation presents difficulties for governments in terms of enforcing economic regulations, taxation, and preventing illicit financial activities, such as money laundering and fraud, [3,5].

Addressing the use of digital currency in social criminal

* Correspondence:
s.tavakoligopaygani@student.unsw.edu.au

activities and the associated challenges for governments requires a multi-pronged approach aimed at enhancing transparency, regulation, and enforcement. This comprehensive solution, proposed by Leuprecht encompasses several key strategies, [4]. First and foremost, it advocates for the development and implementation of an enhanced regulatory framework tailored specifically for digital currencies. These regulations should address issues related to Anti-Money Laundering (AML), Know Your Customer (KYC) requirements, and taxation, thus establishing a solid legal foundation for the digital currency market. Furthermore, this solution emphasizes the importance of international collaboration among governments and regulatory bodies. Know Your Customer (KYC) standards are designed to protect financial institutions against fraud, corruption, money laundering and terrorist financing. Strengthening cooperation at a global level can lead to consistent and harmonized regulations, prevent regulatory arbitrage, and ensure that illicit actors cannot exploit regulatory gaps in different jurisdictions. Lastly, the proposal calls for investments in cutting-edge technologies and resources to monitor and analyse cryptocurrency transactions. This proactive approach will assist in identifying and tracking illicit activities, ultimately making the digital currency ecosystem more secure and transparent. One limitation in controlling the role of cryptocurrencies in social and economic criminal activities is the ever-evolving nature of technology. creating a continuous challenge in staying ahead of illicit activities. To enhance the clarity and understanding of the comprehensive approaches taken for preventing criminal activities associated with cryptocurrencies, it is imperative to delve deeper into the specifics of each strategy. Categorizing these approaches can provide a structured framework for readers. For instance, under the umbrella of regulatory frameworks, one can categorize strategies related to Anti-Money Laundering (AML), Know Your Customer (KYC) requirements, and taxation as distinct subcategories, [4,5]. Additionally, within international collaboration, highlighting specific collaborative initiatives and their impact on preventing cross-border illicit activities would offer a more nuanced perspective. In the technological realm, further explanations about the cutting-edge technologies and resources proposed for monitoring and analysing cryptocurrency transactions can be provided. This categorization not only aids in organizing the information logically but also facilitates a more detailed comprehension of the multifaceted strategies employed to curb criminal activities. As governments and regulatory bodies adapt their strategies, criminals may also develop innovative methods to exploit digital currencies, creating a continuous challenge in staying ahead of illicit activities.

Environmental Aspect of Cryptocurrency Usage

It is necessary to recognize the environmental aspects, especially in the context of some cryptocurrency mining methods, such as proof-of-work, which have attracted considerable attention due to their environmental footprint. Therefore, effective solutions must be identified and implemented to prevent the negative social and economic effects of digital currencies. To mitigate the environmental impact of energy-intensive Proof-of-Work (POW), it is recommended to adopt Proof-of-Stake (POS) as an alternative consensus mechanism in blockchain networks, [6,7]. POS selects validators to create new blocks based on their economic investment in the network, eliminating the need for the resource-heavy mining process. Unlike POW, which often necessitates costly and specialized mining equipment, POS allows a broader range of participants to engage as validators, as it primarily relies on token ownership. POS represents a progressive alternative that significantly reduces the carbon footprint. For example, the transition from ETH to Ethereum 2.0 (ETH2) reduces energy consumption and environmental impact significantly by replacing energy-intensive POW with the more sustainable POS consensus mechanism, [6,8]. One major limitation in transitioning to eco-friendly consensus mechanisms like POS is the resistance from established mining communities. Miners heavily invested in traditional POW systems might resist the shift due to financial interests, creating challenges in the widespread adoption of POS and delaying the reduction in environmental impact, [6,7].

Conclusion:

In conclusion, in parallel with the increase in popularity and acceptability of digital currencies, their use in financial and social criminal activities will increase and have higher destructive environmental effects. The criminal exploitation of cryptocurrencies poses a threat to economic stability and social trust. To address these issues, comprehensive solutions must be implemented. Regulatory frameworks tailored to digital currencies, such as KYC and taxation, could improve transparency. Furthermore, transitioning to environmentally friendly consensus mechanisms, such as POS, should reduce the environmental impact of mining processes. Despite the sustainability benefits of POS, challenges such as centralization and technical complexity remain. If these measures are not implemented, criminal activity, trust, and environmental degradation are likely to increase. Effective decisions and policies must be adopted to ensure the responsible and sustainable future of digital currencies, protecting both economies and the environment.

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Review Open Access

Interoperability and Standards in Blockchain-based EHR

Hossien Aghahosseini [1], Mehdi Sakhaei-nia [1*]

1. Computer Engineering Department, Engineering Faculty, Bu-Ali Sina University, Hamedan, Iran

Abstract

Blockchain technology offers a decentralized database that enables the registration and maintenance of electronic health records (EHRs) through the implementation of encryption policies to ensure privacy. The inherent properties of decentralization and immutability in blockchains make them a practical choice for serving as a database for recording EHRs. Given that EHR files are typically generated by various entities such as hospitals, laboratories, clinics, and mobile applications, it is possible to store each set of collected data in separate blockchains adhering to different standards. However, due to the requirement for real-time access to medical records and concerns surrounding confidentiality and privacy, it is imperative that EHRs registered on different platforms are able to interact with one another online. Therefore, interoperability becomes a fundamental necessity for blockchain-based EHR systems. This paper aims to survey existing research on the implementation of interoperability in EHRs using blockchain technology. The study's findings suggest that achieving a comprehensive solution involves ensuring that all stakeholders follow standardized EHR protocols when recording information. Furthermore, it is advised to use cloud databases for storing large-scale EHR data, while limiting blockchain data storage to identity information and maintaining the integrity of cloud-stored data. To effectively enforce these processes, blockchain smart contracts are utilized. By employing these mechanisms, blockchain can serve as a suitable platform for recording and maintaining interoperable EHRs. Additionally, a detailed multi-layer software architecture is a common practice in the field, even though there is no consensus on the role of 3rd party auditors in it.

Keywords interoperability, blockchain, EHR

1. Introduction

Electronic Health Records (EHRs) refer to the digitized versions of patients' medical records, encompassing comprehensive information such as treatment history, medical prescriptions, radiology images, laboratory results, and allergies. EHRs are accessible online and patient-centric records while maintaining strict confidentiality. It is imperative that authorized users have the ability to real-time access and modify their own EHR data [1].

EHRs should be designed in such a way that they can be shared between different healthcare centers to improve coordination between centers and thus improve the quality of health care. [2]

The design of EHRs should facilitate seamless sharing between different healthcare centers to enhance coordination and improve the overall quality of healthcare [2].

* Correspondence:
sakhaei@basu.ac.ir

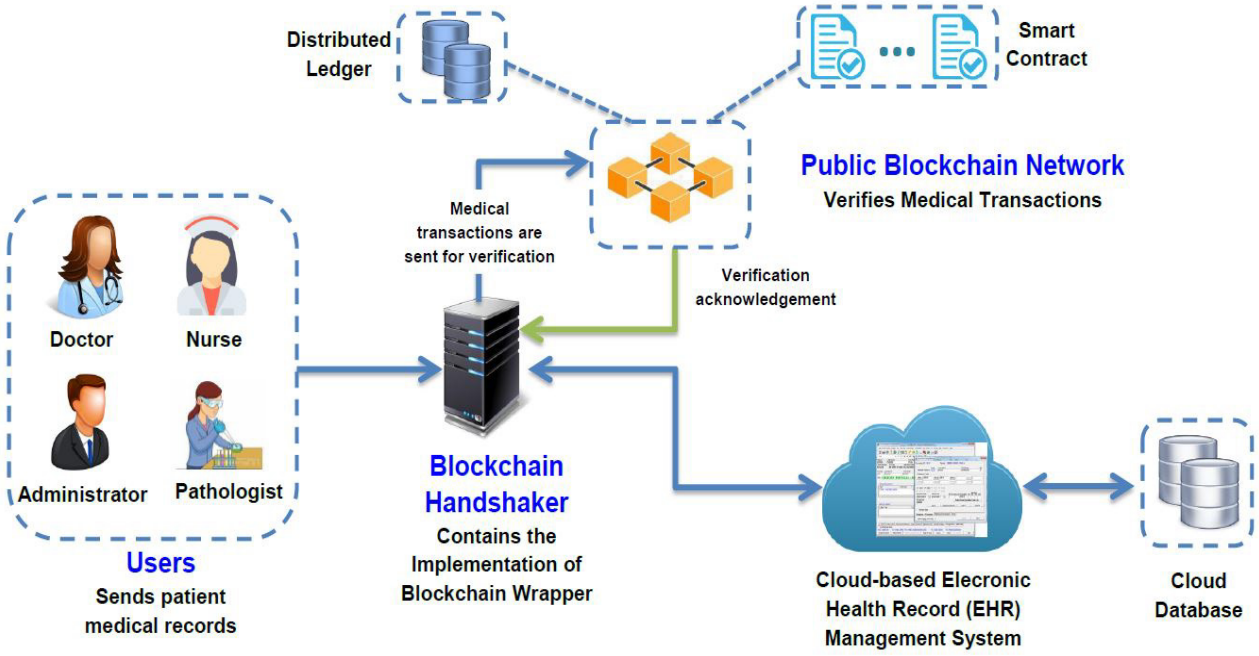

Fig 1. A System Architecture for Blockchain-based EHR Systems by Rahman et al. [11]

Blockchain technology, initially introduced as the foundation for Bitcoin cryptocurrency in 2009 by Satoshi Nakamoto [3], offers a decentralized database solution that possesses key features such as immutability, decentralized management and access control, and robust data security. Consequently, blockchain has emerged as a promising option for storing EHRs, leading to numerous research endeavors in this domain in recent years [4].

Leveraging blockchain as an EHR database can foster interoperability; however, it also presents its own set of challenges and issues. Firstly, the choice of blockchain type warrants consideration. The implementation can be based on existing open-source blockchains or a new blockchain can be developed from scratch. Additionally, determining whether the ownership of the blockchain should be private, public, or consortium-based is another crucial aspect that demands attention [5]. Using or not using smart contracts also makes another issue [6].

The next issue that should be considered is the EHR standard used, to register patients' health records. Different national and international organizations have each considered different standards for EHR registration, which should either be chosen as the standard for data registration in the blockchain, or a mechanism for converting EHRs based on different standards should be considered [7].

The storage location of medical records is another challenge; Since EHR data is voluminous, storing it inside the blockchain can be costly and slow down the speed of information access [8]. To solve this problem, cloud solutions can be used and combined with blockchain; however, in this way, EHRs will not be definitively immutable, and we will need other preventive mechanisms as well to maintain the integrity of EHR data [9].

In addition, the presence or absence of a third-party auditor should also be checked; should there be a member in the network who individually or collectively monitors the recorded data and requests on the blockchain side, or should all members have the same level of access? This issue should also be considered [10].

To overcome these problems, researchers have developed architectures and software platforms that include blockchain-based EHR with interoperability, and have provided different auxiliary mechanisms and components for it, each of which has covered the existing challenges in a way. The results of these investigations showed that, for this issue, a software architecture is used, which initially forces the stakeholders to use the same standards to record EHR information. Identity data and small information are stored on the blockchain, then to solve the scalability problem, a cloud database is used to record voluminous medical information, and a pointer to cloud data is recorded on the blockchain to maintain the integrity of the data. In order to access the data, permission to read the information will be granted to authorized users through encryption mechanisms. Smart contracts in blockchains are also used to enforce the above processes. By using these mechanisms, blockchain can be used as

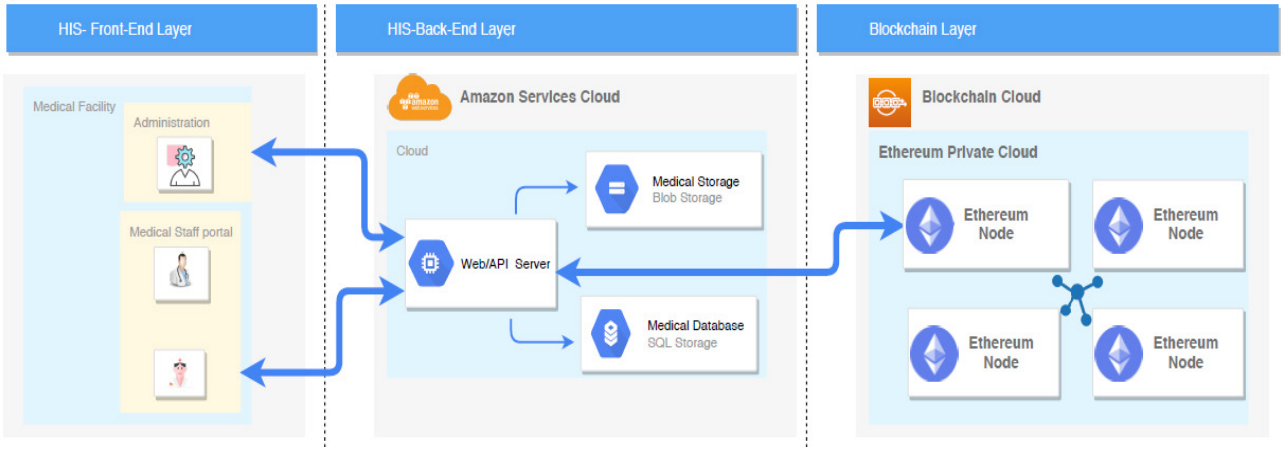

Fig 2. The architecture of Jaber et al.'s solution [15]

a suitable platform for recording and maintaining EHRs while considering interoperability.

The rest of the paper is organized as follows: the basic concepts are mentioned in the section 2. In section 3, the research works has been reviewed. In section 4, we compare the works done and then there is a discussion about the researches and in section 5, the summary and conclusion are presented.

2. Basic concepts

EHRs are necessary in today's world as EHR can create a platform for patients to access medical information, increase patient participation in medical decisions, and facilitate communication between patients and medical centers [1].

2-1- Interoperability in electronic health records

Interoperability is one of the quality features in software systems, which according to the IEEE definition refers to the ability to exchange information between two or more systems and use the exchanged information [12]. Medical organizations such as NAHIT have supplemented this definition for medical purposes and define interoperability as the ability to communicate and share data in a robust, efficient and accurate manner by software systems and information technology systems, along with the ability to use shared data [13].

Applying interoperability in maintaining and sharing EHRs is very important for the many reasons. Easy and fast access to EHR is one of these reasons. EHRs are created in different ways; Hospitals, laboratories, clinics, as well as body sensors, create EHRs separately in their databases [14].

In order to access this type of distributed data, each of the stakeholders of the system, including the patient, doctor, hospital, etc., should be able to easily and quickly access the files of other organizations, which can be even critical. Apart from the above, factors such as eliminating human error, increasing the efficiency of health service providers, reducing the costs of moving medical information are also among the benefits of applying EHR interoperability [15].

2-2- Blockchain and interoperability in EHR

A blockchain is a growing list of records maintained in a distributed manner by peer-to-peer groups. Due to the existence of features such as immutability, decentralized management and access, elimination of the single point of error, pseudo-anonymity, confidentiality, integrity and availability of data in the blockchain, this technology is suitable for use as a database for maintaining EHRs, and in recent years, many papers have been written in this area of research [4].

The blockchain can be maintained by stakeholders in a distributed manner and each stakeholder can record their medical data as a transaction within the blockchain and finally share it. It is also possible to access the medical records of other stakeholders (if permission is granted) using this blockchain. Through the consensus mechanism in the blockchain, all stakeholders can agree on medical data too.

Considering the above factors, blockchain can be considered a suitable platform for realizing interoperability in the field of EHR. However, many challenges such as implementation complexities, high volume of medical data, scalability, diversity of blockchains, data storage location, trade-off with security issues and lack of standard communication protocols can cause problems in achieving complete interoperability [16].

In addition, considering connection problems between different EHR based blockchains with different structures

(such as different transaction structures) and also the variety of standards used in EHR, and different methods of sending data in blockchains, new issues are still created in the field of interoperability of blockchain-based EHRs [17].

3 - Conducted researches

In 2020, Jaber et al. [15] tried to solve the issue of interoperability in EHR by building a software architecture based on cloud and blockchain and the existence of a trusted distributed third-party auditor. The presented architecture consists of two main parts: Health information center (HIS) and BiiMED Blockchain.

The health information center itself includes two layers: The front-end layer is web portals that allow doctors to interact with medical information, and the back-end layer is the cloud system and web services that provide storage and access to medical information.

To record medical information, the ICD-10 standard provided by the World Health Organization (WHO) have been chosen and to record and store medical images the DICOM standard have been used.

The BiiMED blockchain is a private blockchain based on Ethereum and smart contracts [18] that is responsible for the management and validation of shared medical information and plays the role of a trusted distributed third-party auditor.

The system works as follows: users, who are health workers, register medical information in the cloud system using the front-end layer and simultaneously a hash of the data is stored in the blockchain. Each stakeholder, for example, each hospital, keeps its medical data separately, and normally they do not have access to the medical data of others.

If a user wants to access the medical file of a person located in another stakeholder database, he sends a request to the desired cloud system through the web portal and web services, and if permission is granted, the desired medical data will be shared for that user.

To validate the received data, the web services of the web portal first hash the data and then look up the data key in the BiiMED blockchain. If the created hash is equal to the hash in the blockchain, it means that the integrity of the information is preserved and the user can use the shared file.

The strength of this system is the use of the cloud to store and solve the problem of scalability and speed of data access in the blockchain [19], but since the data itself is not stored on the blockchain, there is no guarantee that the data will remain integrate forever; Because the permanent storage of data while maintaining integrity is guaranteed on the blockchain, not on the cloud, and this strength can also be a weakness of the system.

In addition, the existence of a trusted third-party auditor can also be a weakness; because this auditor has the ability to confirm and validate invalid medical data with the cooperation of stakeholders. Although due to the use of distributed blockchain, the third-party auditor can no longer be considered as a single point of failure, but the problem of intentional error still remains.

BiiMed has not been released in real world, but they used some metrics to evaluate the performance of their system. According to their results, when using a single 8GB RAM, Core i7 system with 10000 users, the average response time of read functions are between 1 to 20 milliseconds. As their result is based on a single system, the distributed nature of the blockchains is not addressed and their result should not be trusted in real world deployment of it.

Villarreal et al. [13] also presented another paper in this field which was published in 2023. This paper first reviews the interoperability issues in blockchain-based EHRs and then presents a blockchain-based EHR architecture using a domain-specific language (DSL) and smart contracts.

The proposed architecture is such that each stakeholder (for example, hospitals) has its own blockchain-based EHR database. Each of the blockchains can have different standards for accessing information, and also the mechanism of their smart contracts can also be different.

To access the medical information of other hospitals, Model Based Engineering (MBE) has been used to create interoperability features. In this way, a request to access information/add a record is created first. This request is then translated into a specific DSL-based format. Then this translated request, according to the type of blockchain in which the requested record is located, is converted into a smart contract inside that blockchain, and by using that smart contract, the end user can access the required medical record.

This paper only presents a model based on the translation of smart contracts, but does not implement it, it only introduces the Eclipse Modeling Framework as the platform for modeling smart contracts and converting them with Java language and in the XML format.

Sonkamble et al. [20] published another paper that examines and presents a solution on interoperability in blockchain-based EHR.

In this paper, the concept of interoperability is divided into two categories: structural interoperability and semantic interoperability. Structural interoperability defines the syntax, format and standard representation of data, but semantic interoperability means that the sender and receiver of the data, must have the same understanding of the shared information, and in the translations that take

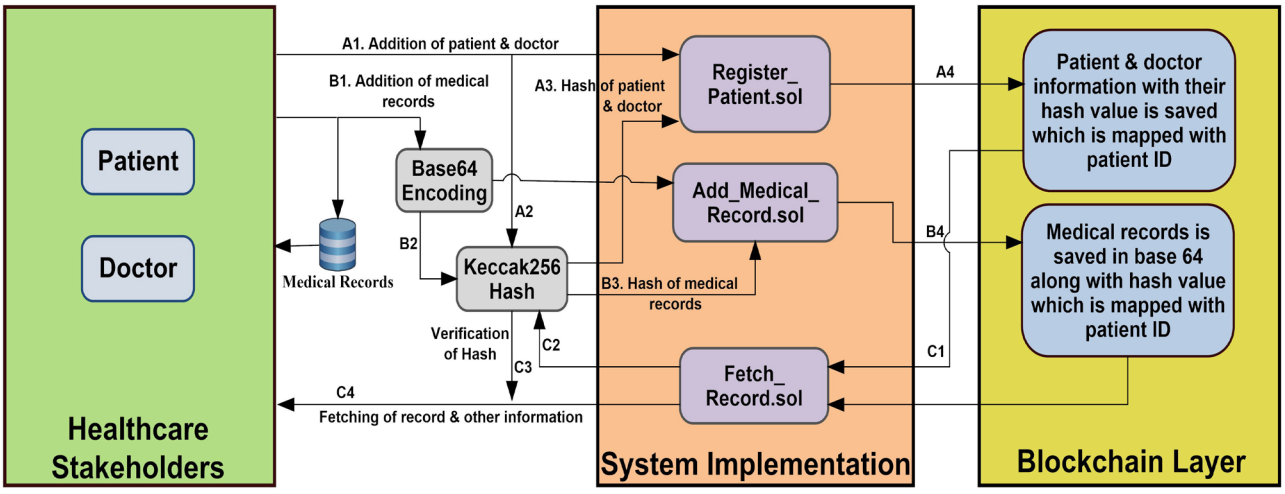

Fig 3. User interaction in MyBlockEHR [20]

place during the sending and receiving of the data, the meaning of the data should not change [21].

One of the strengths of this paper is the systematic review of the standards presented in EHR sharing and the study of the most used ones. One of the most widely used EHR sharing standards is the OpenEHR standard, where patient and clinical trial records are maintained in a standardized format. The use of this standard can help ease the issue of interoperability in EHR. Apart from OpenEHR, the FHIR standard also provides a lightweight solution for EHR modeling using XML and JSON formats, which has higher portability.

This paper then examines the ways of interoperability between different blockchains and reaches three categories. The first category is based on the connection between two blockchains by a third-party auditor called a notary, which can be single or include several members with different digital signatures. The second category is based on side chains and smart contracts. In this way, through smart contracts, a blockchain can read the information of another blockchain and store the part of the information it wants on its side chain. The third category is called Hash Locking, which works by activating the same hash at a certain time in two blockchains.

After reviewing the existing solutions, they present their proposed solution called MyBlockEHR; In MyBlockEHR, users are divided into three categories: patients, doctors, and certificate authorities. Users are responsible for their data and are responsible for granting access to their data to doctors using cryptographic mechanisms.

In order to store data, EHR records are divided into two parts. The first part, which is stored on-chain, contains sensitive and light data plus the hash value of the second part, and the second part, which is stored off-chain, contains large data (eg, medical images) stored in the document-based NoSQL database MongoDB on the cloud storage. The reason for dividing the data into two parts is the greater scalability and the high cost of storing large chunks of data in the blockchain.

Smart contracts are used to access information and validate off-chain information received from MongoDB; In this way, the contracts receive the information and index needed to access medical data from the blockchain, and after receiving them from the off-chain database, it calculates its hash and compares it with the hash stored in the blockchain; If the two hashes are equal, the integrity of the information is confirmed and the data will be provided to the users.

MyBlockEHR hasn't been deployed in real world yet, but it is tested in an isolated platform using an Ubuntu PC with 7.6 GBs of RAM and an 8th gen Core i5 CPU. In its test they wanted to show the difference between the response time of storing EHR data on-chain or off-chain. To do so, they used Ethereum and its smart contracts written in Solidity Language and a local MongoDB database was used as EHR database. According to their results, accessing patient data while stored off-chain can be as fast as about 49 milliseconds, while accessing on-chain data can take as long as about 44 seconds, meaning that storing the actual data off-chain can greatly improve performance.

Carter et al.'s paper [22] has also solved the problem of interoperability in blockchain-based EHRs by using smart contracts and storing the original medical records in the cloud, and has reached the prototype architecture implementation stage. Each EHR provider (such as hospitals) is considered as a node in the Ethereum blockchain. When a provider wants to release a patient's medical record, they

Table 1. Comparison of the reviewed papers

Paper	Blockchain	EHR Standard	Data Storage	Software Architecture	Audit
Jaber et al. [15]	BiiMed Private blockchain based on Ethereum-Based	ICD-10 DICOM	Cloud. Data hash in blockchain	Two layers. Health information center and blockchain	Trusted distributed third-party auditor
Villarreal et al. [13]	Separate and arbitrary blockchain for each stakeholder (hospital)	Translation between different standards	Separate blockchains for stakeholders	Communication between blockchains by smart contracts	None
Sonkamble et al. [20]	MyBlockEHR private blockchain	OpenEHR, FHIR	Off-chain (MongoDB) along with their reference key on the blockchain	Access to off-chain data by smart contract	CA for membership and certification authority
Carter et al. [22]	Ethereum-Based	FHIR	Amazon cloud services	Bucket memory. Envelope encryption	None
Dagher et al. [23]	Ethereum-Based	unknown	Large data on mongo DB, its hash and query on blockchain, small data on blockchain	Three parts. Database, encryption, Ethereum Go client	None

first encrypt it using envelope encryption. Envelope encryption is done in such a way that first the original data is encrypted with a unique key of the data file itself, then the key of the file itself is encrypted once again with another key. After creating the file, it is uploaded to the bucket memory of a cloud storage. When a file is uploaded to the bucket memory, a smart contract is generated declaring that a node has published a medical data. Nodes that have received this message can try to decrypt the message with their key-pair. If they succeed in decryption, (they were given access) they get the key of the published EHR file and can use that key to decrypt the uploaded file.

Amazon AWS cloud service is used due to the existence of encryption services and Ethereum blockchain is used due to the existence of smart contracts. EHR files are created using the FHIR standard.

Their paper doesn't feature any implementation tests and results and any kind of implementation or real-world deployments are left for future works.

Dagher et al. [23] have also presented another blockchain-based EHR paper with interoperability. The provided software platform called Ancile consists of three components. The first component is the database manager. Ancile stores the query link to the database and its hash on the blockchain to maintain integrity, but the medical records themselves are kept off-chain on another database and can be accessed through the query link of the corresponding record in the blockchain. The database manager is in charge of the connection between the blockchain and the database through the creation of hashes and query links. The second component is the encryption manager, which is responsible for encryption and decryption. A public/private key mechanism is used to grant access, but symmetric cryptography is used to store large data. The third component is the Ethereum Go client.

Several smart contracts are used to communicate with the blockchain, which are also able to communicate each other. These contracts can determine the ownership of medical records using relationships between network nodes. In this way, a patient can grant a doctor access to information, revoke access by changing the key, see the history of access to his data and so on.

In order to access information, a user finds the owner of the desired data (for example, a hospital) through a smart contract, and then sends a request to that owner to receive the symmetric key of the corresponding data. If it is available, the key will be returned and the user can access the desired EHR medical record.

In addition, in this system, it is possible to store small medical files (for example, a medical prescription) on the blockchain itself.

In order to evaluate Ancile's performance, they compared its Ethereum gas cost to Medrec [24] which is another blockchain based EHR platform. According to their results, although Ancile has higher gas cost and even higher performance cost than Medrec, their security features are so much important and vital that they willingly pay its price as there is always a trade-off between performance and security.

4- Discussion

There are various ways for using blockchains to implement interoperability in EHR, and each of the reviewed papers has chosen one of them for implementation. Here, for each paper, the type of blockchain used, the EHR standard chosen to record medical records, the storage location of those medical records and the type of database used, the presence or absence of a third-party auditor and

supervisor to the system, and finally their software architecture is checked and compared and the results are given in Table 1.

By examining and studying Table 1, you can get important results; First of all, all the papers reviewed by us have used a specific software architecture and intended to provide a complete software platform. In these software architectures, various encryption mechanisms are used to register and determine user access to EHR data. There is no agreement on the use of a trusted third-party auditor, two papers have used a trusted auditor while three papers have not. Also, the smart contracts available in blockchains are used in three out of five papers in order to enforce the above processes.

The software architecture in the presented papers has forced the users of the services to use a specific EHR standard, and apart from one paper that utilizes the ability to convert EHR standards, other papers have used a specific standard for EHR registration; FHIR standard is used in two out of five papers and other standards such as OpenEHR, ICD-10 and DICOM are also used once in other papers.

By checking the Table 1, you can also get tips about the storage location of EHR data; First of all, there are identity data that must be stored on the blockchain. But EHR documents, due to their high volume, are stored on a cloud database in four out of five reviewed papers, and only a pointer or a hash of that data is stored on the blockchain to maintain integrity. Other than them, one paper has also provided the ability to store small EHR data on the blockchain itself.

There is no definite consensus regarding the type of blockchain used. Two of the five papers have developed a private blockchain, two papers have used Ethereum, and one paper has allowed the use of any type of blockchain and solved the interoperability problem by translating between them.

4-1- Research limitations

In the process of obtaining the papers and information, we encountered some challenges that we will briefly mention. The first issue is the number of papers; Due to the novelty of the topic of examining interoperability in EHR registration on the blockchain, very limited groups have worked in this field in a professional manner, and much fewer people have published it as papers [25]. The second problem is the lack of implementation; Published papers often remain in the theoretical stage and none have been practically implemented and tested in the real world. This causes hidden weaknesses and challenges in using blockchain as a platform to implement interoperability in EHR records that have not been explored. The third issue is the excessive use of Ethereum and smart contracts by working groups; Instead of developing new blockchains with creative consensus mechanisms and using intra-blockchain solutions, the authors of most of the papers have been content with Ethereum smart contracts and finally, by storing the EHR in the cloud, they have only used the blockchain as a platform for registering smart contracts and the features of immutability and integrity that blockchain provides for data have not been used practically so that the integrity of EHR data is still at risk. The existence of these weaknesses creates areas for future researchers to solve the problems of storing EHR data on the blockchain, while providing interoperability.

5 – Future Research Areas

Blockchain integration to ensure interoperability of EHR data is still relatively new and there are still many unexplored aspects in this research area. Novel Blockchain technologies with new consensus methods, not only provide much better scalability, but also, they offer fast transaction confirmation time. Using these blockchains or developing specialized consensus methods for Interoperable EHR blockchains can increase performance by a far margin. Also, the removal of cloud services and using the blockchain as the sole distributed database can also be considered as it can ensure near perfect integrity of data and with these new blockchain technologies it can be possible. DAG based ledgers can be considered as the successors blockchains, DAGs help us achieve simultaneous transaction approval from different stakeholders using their directed acyclic graph structure, which can help us provide much better scalability. [26] Considering DAG as solution for interoperable EHR database can also be a new research area.

6 – Conclusion

Traditionally, EHRs are kept separately in the internal databases of different medical centers, and if a patient wants to transfer a part of his records to another medical center, he needs interoperability between the two medical centers. Blockchain, as a distributed platform for safe and unaltered data storage, can be a suitable database for storing and integrating patients' medical records that can improve interoperability between centers, and for this reason, in recent years, many solutions in this field has been provided.

Due to the problems of scalability and the high cost of storing large volumes of medical data on the blockchain, researchers have decided to store the medical data itself in the cloud and store its pointer and hash in the blockchain. In addition, medical data should be stored according to global EHR standards, like OpenEHR and FHIR,

to improve interoperability and reduce or even eliminate the need for translation.

In this case, any provider of medical data (for example, a hospital) as long as it uses EHR standards can store its medical data on the cloud space of its choice and store only its hash and pointer in the main blockchain to ensure scalability through cloud storage and data integrity through blockchain.

In order to access blockchain data, the smart contracts available in Type 2 blockchains, such as Ethereum, are usually used to reduce human error and to enforce the information access process. It is also possible for the EHR to be stored in two different blockchains, in this case, it is necessary to interact between the two blockchains using methods such as smart contracts or a trusted interface.

Finally, it can be said that blockchains can help interoperability between EHR centers, provided that EHR standards and appropriate encryption techniques are used. The use of cloud space and NoSQL document-oriented databases to maintain EHR and store their pointer and hash in the blockchain is also very common in this area.

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Consent for publication
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Original Open Access

Assessment of the potential ameliorative role of *Origanum vulgare* on permethrin-induced toxicity

Ehsan Zayerzadeh [1*], Reza Abbassi Larki [2]

1. Food Toxicology Research Group, Research Center of Food Technology and Agricultural Products, Standard Research Institute, Karaj, Iran
2. Department of Microbiology, Karaj Branch, Islamic Azad University, Karaj, Iran

Abstract

Origanum vulgare (O. vulgare), is a medicinal plant which is traditionally used to treat different diseases. In this study, we evaluated the potential protective effects of *O. vulgare* against the toxic effects of permethrin (PM) in rats. Thirty adult rats were orally treated with normal saline as a control group, PM (150 mg/kg) as the second group, and (PM (150 mg/kg) + *O. vulgare* (300 mg/kg)) as the third group, once a day for 21 consecutive days. After completion of the study, clinical signs and body weight were assessed. Tissues and blood samples were collected for histopathological examination, biochemical alterations, and hematological analysis. The findings of this study demonstrated that PM induced some clinical signs and significantly declined the body weight of the treated rats. The tissue sections of animals in the second group showed some tissue complications in the liver, heart, lung, and kidney. In addition, hematological parameters including WBC, RBC, Hb, HCT, MCV, MCH, PLT, and biochemical parameters including ALT, AST, ALP, BUN, and creatinine were significantly changed. On the other hand, in the third group, *O. vulgare* reduced hematological, biochemical, and histopathological abnormalities, significantly. Furthermore, this plant could improve clinical signs and body weight changes. In conclusion, our results demonstrated that *O. vulgare* could be a potential herbal medicine for reducing the toxicity of PM.

Keywords *Origanum vulgare*, permethrin, toxicity, rats.

1. Introduction

Pesticides are an important group of environmental pollutants. Environmental contamination of pesticides is a threat to life because pesticide residues are found in the food chain, soil, and water. The pyrethroids are popular insecticides with extensive applications. They consist of two groups according to their chemical structures. Type I pyrethroids are without α-cyano moiety at the α-position such as permethrin (PM), while; type II pyrethroids have α-cyano moiety such as cypermethrin [1-2]. PM is one of the most widely-used synthetic pyrethroids with a wide spectrum insecticidal activity, which is used to control different pests in agriculture, veterinary, and domestic in the world [2]. This insecticide is applied in sprays, pet flea shampoos, lice shampoos, and home mosquito abatement products. It is also applicable on agricultural crops, particularly fruits and vegetables. Humans can be exposed to PM with ingestion of contaminated foods or inhalation of polluted air. Occupational exposure can happen via both inhalation and dermal contact at workplaces where PM is manufactured or used [2, 3]. Although scientists believe that pyrethroids are safer than organochlorines,

* Correspondence:
zayerzadeh@standard.ac.ir

organophosphates, and carbamate pesticides, the European Union (EU) classifies permethrin as hazardous to the environment [4], and an increasing number of investigations have demonstrated that PM can induce a variety of toxicities in animals and humans, such as carcinogenicity, neurotoxicity, immunotoxicity, cardiotoxicity, hepatotoxicity, reproductive toxicity, digestive system toxicity and cytotoxicity [5-11]. As we know, there is no special antidote for pyrethroids poisoning. As a result, treatment is supportive and symptomatic. In this regard, the identification of new ways for treatment of pyrethroids poisoning will be valuable. Traditionally, the use of plants for the treatment of different poisonings was popular because many of the plants have no adverse effects. One of the most precious plants is *O. vulgare* which grows in Iran extensively. This plant is used to treat hyperglycemia, leukemia, and other diseases. The major constituents of this plant are rosmarinic acid, eriocitrin, luteolin-7-oglucoside, origanol A and B, and ursolic acid. This plant demonstrated a potent antioxidant and free radical scavenging feature [12]. On the other hand, one of the most important mechanisms for pyrethroids poisoning is stress oxidative. Therefore, *O. vulgare* may be effective for treating pyrethroids poisoning which is related to stress oxidative. As far as we know, there is no study in the field of the protective effects of *O. vulgare* against pyrethroids poisoning in experimental animals. Therefore, in the present investigation, we assessed the potential ameliorative effects of *O. vulgare* against the toxic effects of PM in rats.

Materials and methods

Animals and test materials

Thirty adult Wistar rats were bought from the Pasteur Institute of Iran. All rats were housed in separate cages and allowed to be adapted with lab environment before the experiment. After a period of one week adaptation to laboratory environment, rats were randomly allocated into 3 groups. They were kept under hygienic and standard conditions (temperature of (22 ± 2)°C, humidity (55 ± 5) %, and a 12:12 light/dark cycle) with adequate standard laboratory food and tap water. All animals were kept according to the recommendation of the animal care committee of the Tehran University based on the 'Guide for Care and Use of Laboratory Animals' (NIH US publication 86-23, revised 1985). Permethrin (Pale yellow liquid; CAS No. 52645-53-1; purity = 95%) was obtained from Shanghai Bosman Industrial Co., Ltd. (China).

Preparation of extract

O. vulgare plant was purchased from (Zarin giah company, Iran) and the plant samples were identified by a botanist. Then, 50 grams of plant powder were mixed in double distilled water and ethanol for 72 hours. Then, the hydroethanolic extract was filtered, and the filtrate was concentrated through evaporation under a vacuum at 40°C. Then, the extract was kept at -20°C until experiments.

Treatment

Thirty rats were randomly divided into three groups, ten in each group. The first group was the control which received saline. The second and third groups were considered as the experimental groups. A single dose of PM was administered orally by gavage to animals at the dose of 150 mg/kg (second group) for 21 days. In the third group of animals, a single dose of PM (150 mg/kg) and a single dose of *O. vulgare* (300 mg/kg) were administered orally by gavage to animals simultaneously. At the end of the study, the animals were sacrificed by intraperitoneal injection of ketamine (30-50 mg/kg) and xylazine (3-5 mg/kg).

Hematological assessment

Hematological parameters including RBC, HB, HCT, MCV, MCH, MCHC, WBC, and PLT were analyzed using a hemocytometer (ADVIA, Hematology system). The results represent the mean ± standard deviation (SD) per percentage of cell suspension.

Biomarker assessment

Blood samples were collected into the test tubes containing EDTA, kept for 30 min, and centrifuged at 3000 rpm for 20 min. Finally, we separated the serum samples and measured the levels of blood alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), the levels of blood urea nitrogen (BUN), and creatinine by (Model BT3000 auto analyzer Italy and commercial biosystems kits, Spain) using the manufacturer's guideline.

Histological analysis

Tissues such as heart, lungs, kidney, and liver were isolated and immersed in 10% buffered formalin for 48 h at room temperature and then sectioned transversely in 3–4 µm slices. Samples were dehydrated in a graded series of alcohol and xylene and embedded in paraffin. For histological processing, the sectioned tissues were stained with hematoxylin-eosin and examined for morphological and histological parameters by light microscope (Labomed Lx 400, USA).

Statistical Analysis

All data are expressed as mean ± SD. The mean of all parameters between the two groups was compared using the Student's t-test. Data was analyzed using the SPSS software (version 19) and a $p<0.05$ is considered statistically significant.

Table 1. The mean of hematological parameters following oral administration of PM and (PM + *O. vulgare*) in rats.

parameters	First	Second	Third
WBC	8.63±1.32	4.61±0.74*	7.15±1.67**
RBC	6.70±0.97	8.2±1.45*	7.4±1.55**
HB	12.05±1.51	14.2±1.22*	12.51±1.23**
HCT	33.6±5.80	40.25±6.28*	36.7±6.48**
MCV	50.56±1.50	58.05±2.68*	55.07±1.69**
MCH	18.1± 0.97	18.52±1.64	18.47± 1.5
MCHC	34.18±1.16	34.76±3.80	34.91±1.52
PLT	578±187	181±37*	362±49**

Mean values (standard deviation) are shown for ten animals in each group. *significant difference between the second and the control groups ($p<0.05$), ** significant difference between the third and the second groups ($p<0.05$)

Results

Hematological assessment

The mean of hematological parameters in the groups could be seen in table 1. The mean of parameters including RBC, HB, HCT, and MCV in the second group was significantly higher than those in the control group. While, the mean of WBC and PLT in this group was significantly lower than those in the control group. In this group, the mean of MCH and MCHC did not show significant different in comparison with the control group. In the third group, *O. vulgare* ameliorated the mean of RBC, HB, HCT, MCV, WBC, and PLT parameters in comparison with the second group, significantly.

Biomarker alterations

Serum ALT, AST, ALP, BUN, and creatinine concentrations were significantly boosted in the second group of animals compared to the control group. In the third group of animals, *O. vulgare* improved biochemical parameter abnormalities, significantly (Figures 1 and 2).

Histopathological evaluation

Oral administration of PM in the second group induced different histopathological complications such as hepatocyte vacuolation, sinusoidal enlargement, inflammation, and congestion in the liver of animals. Interlobular congestion, distal and proximal cell vacuolation, and degeneration of proximal renal tubules were observed in the kidney of animals. Also, this pesticide induced important pathological abnormalities including interstitial inflammation, hemorrhage and congestion in lungs and congestion in the heart of animals. On the other hand, *O. vulgare* improved histopathological abnormalities in the third group in comparison to the second group (Figure 1).

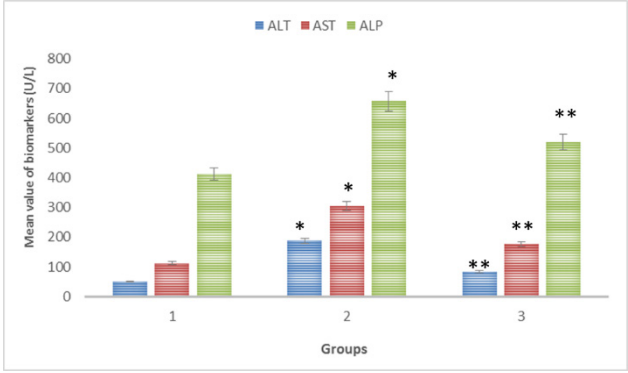

Fig 1. Effect of PM and (PM + *O. vulgare*) on ALT, AST, and ALP blood levels in rats; Values were given as means ± SD for ten animals in each group. *Significantly different from the control group ($P < 0.05$). **Significantly different from the second group ($P < 0.05$).

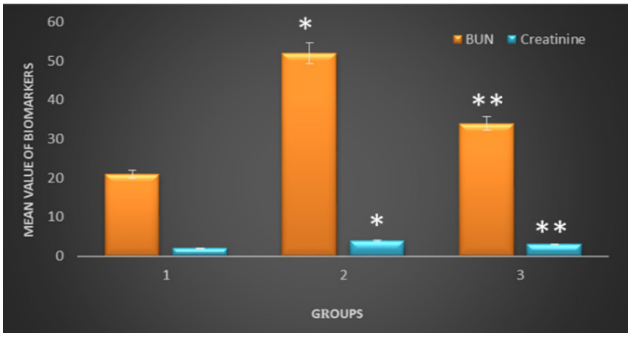

Fig 2. Effect of PM and (PM + *O. vulgare*) on the BUN and creatinine blood level in rats; Values were given as means±SD for ten animals in each group. *Significantly different from the control group ($P < 0.05$). **Significantly different from the second group ($P < 0.05$).

Clinical symptoms and body weight

Mortality was not observed in any of the experimental groups. PM induced some clinical signs such as anorexia, depression, muscular tremors, and ataxia. In addition, this pesticide decreased significantly the body weight of treated rats in the second group of animals. While, oral administration of *O. vulgare* and PM simultaneously improved clinical symptoms and body weight in the third group of rats in comparison to the second group. The body weight of all experimental rats is summarized in Table 2.

Discussion

In this study, we analyzed the ameliorative effects of *O. vulgare* against the toxic effects of PM in rats. The mechanism of action of PM is to interfere with sodium channels, receptor-ionophore complexes, and neurotransmitters. Previous studies have reported that PM can induce a variety of toxicities in animals and humans [9-11]. Our data revealed that oral administration of PM induced histopathological alterations such as hepatocyte vacuolation, sinusoidal enlargement, inflammation, and con-

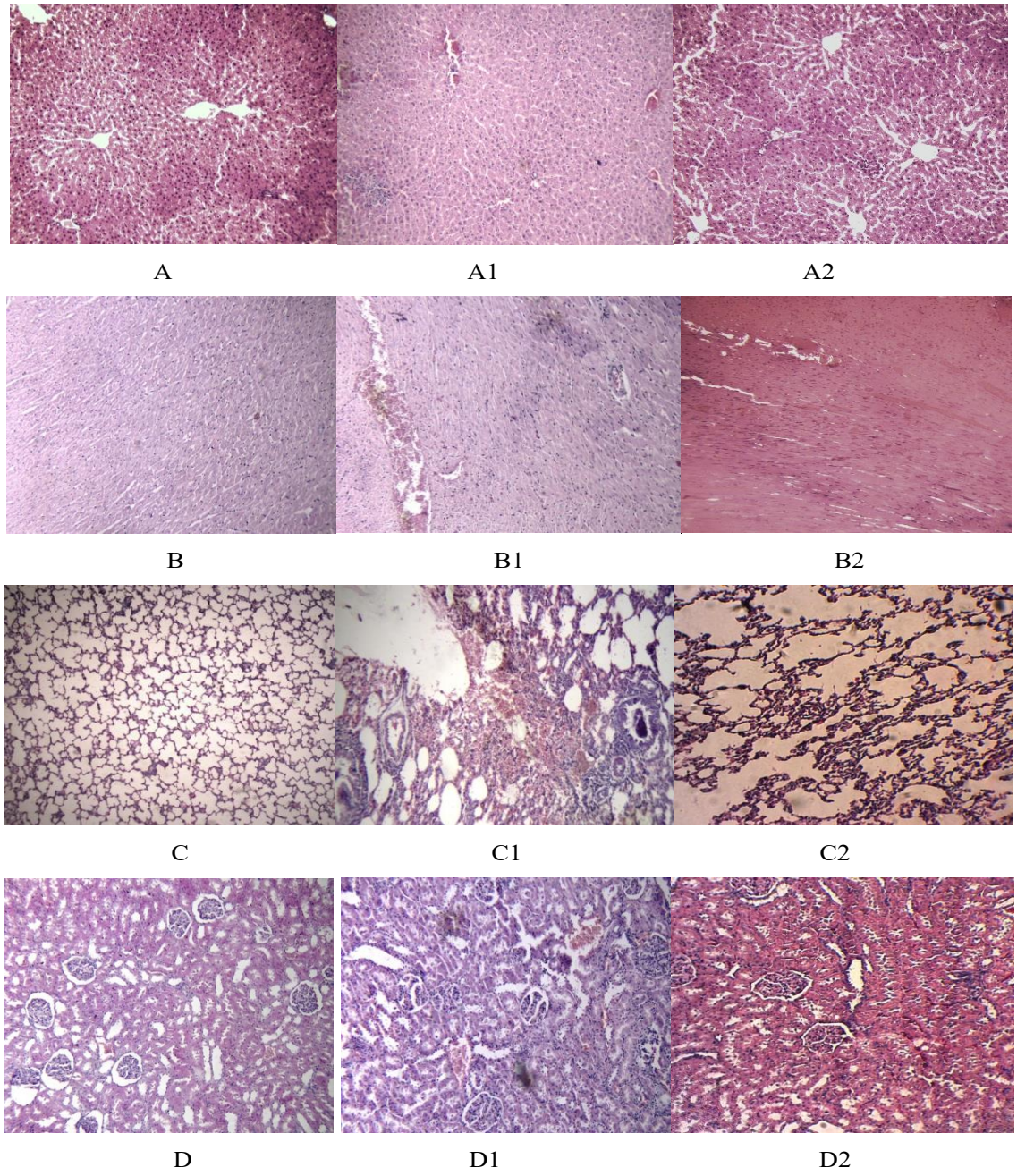

Fig 3. Photomicrographs of liver, heart, lung, and kidney sections were obtained from rats exposed to PM, and (PM + *O. vulgare*). Panels A: normal liver; A1: inflammation, congestion in the liver; A2: mild inflammation in the liver; B: normal heart; B1: congestion in the heart; B2: mild congestion in the heart; Panel C: normal lung; C1: interstitial inflammation, hemorrhage and congestion in the lung; C2: mild congestion in the lung; D: normal kidney; D1: interlobular congestion, distal and proximal cell vacuolation and degeneration of proximal renal tubules in the kidney; D2: mild congestion in the kidney (Staining with hematoxylin and eosin).

gestion in the liver, interlobular congestion, distal and proximal cell vacuolation, degeneration of proximal renal tubules in the kidney, interstitial inflammation, hemorrhage, and congestion in the lung and congestion in the heart of the experimented rats. There are some reports about pathological abnormalities in animals which were induced by pyrethroids. Kotila et al [13] demonstrated negative effects of permethrin on follicular and corpus luteum cell morphology in a dose dependent manner. Furthermore, some studies reported inflammation, congestion, edema, and hemorrhage in some organs following administration of some other sorts of pesticides such

Table 1. Body weight following oral administration of PM and (PM + *O. vulgare*) in rats.

Groups	Bodyweight (g) on the first day	Bodyweight (g) on the last day
First	201 ± 20	311 ± 24
Second	201 ± 22	266 ± 19*
Third	205± 23	301 ± 23**

Values were given as means±SD for ten animals in each group. *Significantly different from the control group ($P < 0.05$). **Significantly different from the second group ($P < 0.05$).

as fipronil and chlorpyrifos in animals. Congestion or hyperemia represents the increase of blood in an organ, due to dilatation of small vessels. However, mechanism of congestion induced by this pesticide is not clear and needs further investigations. Some studies concluded that oxidative stress may be a potential mechanism of toxicity for PM. In addition to stress oxidative, PM can decrease the antioxidant defense system resulting in damage to cellular macromolecules, including DNA, lipids, and proteins [3]. The hematological results in the experimented group demonstrated that parameters including WBC and PLT were significantly lower than those in the control group. Platelets are the blood cells involved in coagulation. The platelets should be in sufficient size, number and function for blood coagulation [14].Our results showed a platelet count reduction, following PM exposure. This result agrees with a study that reported a decrease in platelet count in rats exposed to pyrethroids [14]. The mean values of RBC, Hb, HCT and MCV in the group received PM were significantly higher than the control group. Our results suggest PM treatment may induce abnormalities in bone marrow and hematopoietic progenitor cells. Moreover, the activity of ALT, AST, ALP, BUN and creatinine was significantly raised following PM treatment in rats. The AST and ALT increase is one of the most important indexes in the diagnosis of liver abnormalities. Furthermore, BUN, and creatinine level rise is an essential factor for the identification of renal dysfunction. Our results are compatible with a previous study which indicated that pyrethroids such as cypermethrin could induce liver and kidney failure [15]. In the present investigation, we realized that *O. vulgare* could improve hematological, biochemical, and histopathological abnormalities induced by PM. Furthermore, this plant could ameliorate clinical signs and body weight changes induced by PM. Some plants have special components such as flavonoids and phenolics which have antioxidant and free radical scavenging characteristics, and they could be used as a medicine for the treatment of different kinds of diseases [16, 17]. In a study, Arami et al reported that *O. vulgare* could protect blood lymphocytes from DNA damage and reduced genotoxicity which induced by irradiation [18]. Carvacrol and thymol are the two main phenolic compounds in *O. vulgare*. These components are strong antioxidants. Therefore, the antioxidant activity of *O. vulgare* could be attributed to these phenolic compounds [19]. In another study, Shokrzadeh et al reported that *O. vulgare* could be used to relieve the adverse effects of cyclophosphamide [20]. It has been proved that PM induces toxicity by oxidative stress mechanism. Therefore, *O. vulgare* probably declines toxicity by oxidative stress inhibition.

Conclusion

To sum up, our findings indicate that *O. vulgare* can be a potential supportive herbal medicine for treatment of PM poisoning.

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Declarations

Ethics approval and consent to participate

Not applicable.

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Competing interests

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Case Report Open Access

The Small and Medium-sized Iranian Enterprises' Challenges and Concerns for Benefiting from Standards

(A Case Study in Industrial Towns and Technology Parks in Tehran and Alborz Provinces)

Hoda Aleali [1*]

1. Department of metrology, Research Center of Quality Assessment and Management Systems, Standard Research Institute, Karaj, Iran.

Abstract

Today, Small and medium enterprises (SMEs) play a pivotal role as key drivers of economic growth and innovation in both developed and developing countries. The role of standardization is acknowledged as a robust link between research, innovation and the market, serving as an effective tool for enhancing and disseminating knowledge. Consequently, the standardization process can significantly contribute to economic growth, prosperity and improvement of the performance of these companies. However, a limited number of small and medium-sized companies express interest in participating in the standardization process. Many stakeholders and company executives perceive the standardization system as overly intricate and lack awareness regarding the benefits and importance of standardization in their business operations. In this research, the effective factors affecting lack of standardization of SMEs have been identified using a questionnaire tool. The ordinal weighted average operator and the Shannon entropy method were used in the ranking process to analyze the gathered data. The results reveal that the most substantial constraint in implementing standards is the constrained availability of resources, while the least significant factor is the lack of access to specialized standards. The reasons behind these findings and the recommended solutions are thoroughly discussed.

Keywords Standardization, Small and Medium Enterprises (SMEs), Quality Management, Weighted Average Operator.

1. Introduction

It can be clearly seen that standards as the technical and comprehensive documents facilitate business processes by creating an atmosphere of mutual trust in business processes and have a very strong and constructive role on the growth and economic productivity of a country [1-2]. The ability to easily access specialized information, increasing the speed of technology transfer, improving the penetration rate of technology in products and services, increasing their safety and quality, improving productivity and finally improving the indicators of national economic development are among the most important benefits of standards [3].

In the contemporary global economy, the success of an economy is profoundly reliant on the number and dynamics of small and medium-sized companies in the market. Small and medium companies cover a wide range of activities from home to production and services. In this regard, there are different definitions of small and medium companies among countries. Some of the criteria that are

* Correspondence:
h.aleali@standard.ac.ir

usually used in the definition of small and medium companies are the number of employees, the amount of capital and assets, the total volume of sales and the production capacity. Among these criteria, the most common criteria for defining small and medium-sized companies are the number of employees [4-5]. SMEs are defined by European standards bodies as enterprises with a workforce of fewer than 250 individuals, encompassing a diverse group ranging from small-scale artisanal operations to cutting-edge high-tech companies [6].

To secure more market share in today's unpredictable economic landscape, companies must discern critical success factors. Recent studies illuminate how SMEs not only create but also sustain superior business performance and competitive advantage through their development processes. Various studies have used conventional statistical approaches such as structural equation modelling and multiple regression analysis to determine the key dimensions of enhancing business performance [7-8]. Studies have shown that small and medium-sized companies, in comparison to their larger counterparts, are more susceptible to cost factors, market conditions, and organizational barriers. These factors directly influence the intensity of their investment in innovation [9]. Numerous studies have consistently demonstrated the positive impact of standard in promoting and fostering the growth of small and medium-sized companies [10-12]. However, Veris, et al have pointed out a notable gap in awareness among small and medium-sized companies regarding the benefits of standardization, despite the evident advantage [13].

There are some standard organizations that have recently conducted many studies to help promotion of SMEs performance through standardization process. International Standards published by ISO help small to medium sized enterprises reduce costs, increase productivity and access new markets, build customer confidence, meet regulation requirements, reduce costs. ISO provides a wide range of tips to help SMEs get started with standards to enhance brand recognition and give customers the guarantee that their technology is tested and reliable [14]. The recommendations presented by the European standards bodies CEN and CENELEC pertain to the promotion of accessibility to European standardization for small and medium-sized enterprises (SMEs). The primary aim is to provide solutions that enhance the importance of standardization and standards for SMEs while mitigating their financial consequences. This project focuses on European standards, including their development and standardization, and establishes links between these standards and the business objectives of SMEs.

The new International Sustainability Standards Board (ISSB) plays a pivotal role in addressing the issue of global reporting fragmentation, paving the way for more transparent and consistent reporting practices tailored for SMEs. These standards impart valuable insights to SMEs, illustrating how adherence to the established norms can significantly enhance their firm's credibility and efficiency in sustainability reporting [15].

While numerous studies have aimed to enhance the performance of small and medium enterprises, a comprehensive overview reveals a noticeable gap in direct investigations into the impact of standards and standardization on the performance and development of SMEs [16-18]. Consequently, the primary objective of this study is to discern the factors influencing the limited participation of small and medium-sized companies in the realm of standardization and standards. The ultimate aim is to propose effective solutions to enhance this participation, thereby aiding these enterprises in elevating their quality to meet customer requirements. By considering the factors hindering SMEs from experiencing the advantages of standardization, this study contributes valuable insights to enhance services and overall business operations.

The importance of standardization for SMEs

In the contemporary world, the standardization of goods and services stands as a critical factor influencing competition, driving innovation, and sustaining the continuous progression of production and technology. A successful and impactful presence in both domestic and international markets is entirely contingent upon standardization. Figure 1 illustrates this interactive cycle. This approach, applied to production processes, yields positive effects by ensuring a sustained market presence for capital owners and producers. Simultaneously, it enhances productivity and process effectiveness, resulting in cost savings derived from the reduction of waste and expenses related to after-sales services.

Fig 1. The cycle of standard, production, innovation, economic growth and social benefit

Additionally, it minimizes the need for rework by addressing defective or incomplete goods, parts, and processes [19-20].

Standards can provide a system thinking in management approaches and a structure based on test and knowledge in improving all operational processes of a company, including improving product and service quality, improving customer satisfaction and increasing new customers. From this point of view, the use of standards can be considered as one of the inseparable components of the strategies of companies to be present in the competitive field of the market. In an overview, these benefits can be summarized as following [19,21]:

- Improvement of the quality of products or service
- Demonstrating the company's ability to produce products and provide high quality services
- Increasing intra-organizational trust towards business and manufactured products or services provided
- Improving the image of the company in the market
- Promotion of cooperation and specialized participation based on a common technical language
- Expanding the market and increasing exports
- Technology transfer and up-to-datedness of the products and services provided
- Upgrading the risk management system and improvement of planning
- Reducing costs
- Increasing competitiveness

Research methodology: tools and methods

In this article, the identification of the most significant obstacles and limitations in the utilization of standards by small and medium companies was conducted through data collection employing a questionnaire tool. The statistical population under investigation comprised small and medium companies situated in industrial towns and science and technology parks in Tehran and Alborz provinces. The sampling method employed in this research was deliberate random sampling.

The size of the sample population based on the statistical population of the research was determined by Cochran's method and a questionnaire was distributed to collect information. 116 questionnaires were completed and collected by the senior managers or technical managers of the companies participating in the project and a number of experts from the Iran National Standards Organization. According to Cochran's formula, with an error accuracy of less than 5%, the sample volume was 97, which showed the adequacy of the number of collected questionnaires.

First, the participation level of the SMEs in the field of standards and standardization was determined by asking questions on the two axes of their effective presence in the corresponding international technical committees and participation in the formulation of national standards.

A specialized questionnaire was compiled with the help of a number of company managers and experts in the field of standardization and its tolerance was qualitatively evaluated. In addition to the factors mentioned in the questionnaire, those who completed the questionnaire could also state and record the factors affecting the ranking from their point of view. In the process of ranking and determining the degree of importance of the factors, the ordinal weighted average operator (OWA) was used.

In this article, the OWA operator is used to weight the factors. The weight coefficients were determined using the OWA operator and the Lagrange coefficients method. In the OWA operator, weights are attached to positions, not to values, and this allows the decision maker to fuse different types of information in the process.

The OWA operator was introduced by Yager in 1988 [22]. In a classical definition, an n-dimensional OWA operator is a mapping from

$$F: R^n \rightarrow R \quad (1)$$

which has a weight vector w.

$$W=[w_1,\ldots,w_n]^T \quad (2)$$

where

$$w_1 \in [0,1]$$

$$\sum_{i=1}^{n} w_i = 1 \quad (3)$$

and

$$F(a_1,\ldots,a_n) = \sum w_i b_i \quad (4)$$

where b_i is the largest element of the combined set of objects $a_1,\ldots,a_n$. The value of $F(a_1,\ldots,a_n)$ can determine the aggregation of the value of $F(a_1,\ldots,a_n)$ objects. The weight w_i is associated with a particular sorted position i. The famous feature of OWA operators is that they include the minimum, maximum and average operators for the appropriate selection of the W vector as follows:

$W=[0,0,\ldots,1]^T, F(a_1,\ldots,a_n)=\mathrm{Min}(a_i)$

$W=[1,0,\ldots,0]^T, F(a_1,\ldots,a_n)=\mathrm{Max}(a_i)$

$W=[1/n,1/n,\ldots,1/n]^T, F(a_1,\ldots,a_n)=\mathrm{Mean}(a_i)$

OWA operators satisfy commutability, uniformity, and repeatability properties and are limited by maximum and minimum operators as following:

$$\mathrm{Min}(a_i) \le F(a_1,\ldots,a_n) \le \mathrm{Max}(a_i) \quad (5)$$

Since the OWA operator is limited by the maximum (or) and minimum (and), Yager introduced a scale to specify the type of aggregation for a specific value of the weights vector called Orness scale, which is defined below:

$$orness(w) = \sum_{i=1}^{n} (n-i)w_i \Big/ (n-1) \quad (6)$$

This scale measures the degree to which aggregation behaves like an "or" operator and is considered a measure of the decision maker's optimism.

$$\begin{aligned} &\mathrm{orness}(w)=([1/n,1/n,\ldots,1/n]^T)=0.5 \\ &\mathrm{orness}(w)=([1,0,\ldots,0]^T)=1 \\ &\mathrm{orness}(w)=([0,0,\ldots,1]^T)=0 \end{aligned} \quad (7)$$

Another measure used by Yager is the Shannon entropy. Entropy is a famous operator in information theory, by maximizing it you can make sure that the maximum amount of available information is used.

$$Disp(w) = \sum_{i=1}^{n} w_i \ln(w_i) \quad (8)$$

According to the above equation, it can be concluded that in order to obtain the weights related to OWA, the following relations should be solved, whose objective function is to maximize entropy, considering constraints (3) and (6):

$$MaxDisp(w) = -\sum_{i=1}^{n} w_i \ln(w_i)$$

$$orness(w) = \alpha = \textstyle\sum_{i=1}^{n} (n-i)w_i/(n-1) \quad 0 \le \alpha \le 1 \quad (9)$$

Results and Discussion

The analysis of the answers shows that about 96.8% of small and large companies are not familiar with the corresponding technical committees of international standards and less than 10% of the respondents have participated and played an effective role in the development of national standards.

The obtained results lead to the conclusion that the importance and benefits of standards and standardization may not be adequately understood within the framework of management strategy and development for SMEs. Table 1 provides a comprehensive list of six factors contributing to the limited benefits derived from standardization by SMEs, by using OWA operator weights to aggregate preference rankings.

Our findings show that limitation of resources in the implementation of standards and the lack of knowledge of standardization in the small and medium-sized companies are of the most important factors and obstacles in their use of standards. In some cases, it has been seen that these companies are struggling to get this specialized information, but they are not aware of its existence in the standard documents. This lack of awareness can be caused by two important factors: a) the low level of specialized knowledge of the company's employees b) the lack of effective positioning of the company in the interaction and communication network in its specialized field.

In many cases, these companies are not aware of the potential hidden in standards for the manufactured product or the service provided by them. This issue is more visible especially for companies whose senior managers have participated only with the investment approach and have less knowledge in the technical field. In some cases, due to limited resources, companies emphasize more on short-term strategies, and this short-term view leaves no room for planning and implementing long-term strategies.

The main reason for implementation of a standard is to achieve the set goals of the business, which continuous performance monitoring shows the effectiveness of using these standards. In most small and medium-sized companies, it can be seen that due to limited resources, management is involved in executive and daily tasks most of the time and pays less attention to continuous monitoring and evaluation of processes.

One of the obstacles for small and medium-sized companies to benefit from standards is the lack of the level of specialized knowledge necessary to understand specialized standards and the technical information. This obstacle to the correct understanding of the standard can be caused by factors such as the high level of technical information of the standards, the lack of availability of the standard text in the native language, the lack of providing sufficient information in the preface of the standard regarding the subject matter of the standard and selection and lack of skills and knowledge necessary to understand the standards.

Maybe for some small and medium companies, the process of benefiting and accessing the standards does not seem simple and accessible, and maybe at first glance, the cost of buying these standards is considered as a factor

Table 1. Aggregated rank of factors affecting lack of standardization of SMEs

Factors	Aggregated OWA weight of factors based upon maximizing entropy	Ranks
Limitation of resources in the implementation of standards	0.845	1
Lack of knowledge of specialized standards and standardization processes	0.818	2
Lack of awareness of the importance and role of standards	0.807	3
Absence of evaluation processes and effectiveness of standards	0.790	4
Lack of scientific and professional ability to understand the standards	0.719	5
Lack of access to specialized standards	0.70	6

limiting their use. It should be noted that the price of preparing the standards is not a significant number compared to the quality of the information in them, which is the result of hours of specialized and expert work by a group of legal experts, and for companies it is not a cost, but an investment in the field of research and development.

Conclusions

The importance of small and medium-sized companies and their role in economic development becomes more evident, especially regarding to their impact on the innovation and technology. In this article, most important obstacles and limitations in the use of standards by small and medium companies using a questionnaire tool was studied and identified. The companies under investigation were small and medium companies in industrial towns and science and technology parks in Tehran and Alborz provinces. 116 questionnaires were completed by the senior managers or technical managers of the companies participating in the project and a number of experts from the Iran National Standards Organization. The results showed that 96.8% of small and large companies are not familiar with the technical committees of international standards and less than 10% of the SMEs have played an effective role in the development of national standards. The ordinal weighted average operator (OWA) was used to rank and determine the degree of importance of the factors. Our results introduced 6 factors that make obstacles for SMEs not to experiencing the benefits of standardization. The highest and lowest ranking related to resource limitations of SMEs in the implementation of standards and lack of access to specialized standards, respectively. From the obtained results, it can be concluded that the importance and benefits of standards and standardization are not properly understood for the management strategy and development of the SMEs. So, it is necessary for small and medium-sized companies to find the awareness about the benefits and importance of using standards and participation in standardization processes. Finally, the culture of using standards is considered as a management and strategic requirement in the management system of these companies.

Suggestions

According to the presented results, the following are suggested in order to expand the culture of using standards and participate more in standardization processes. Promotion of communication activities and expansion of standardization culture at the national and regional level through different ways such as radio and television publications, Internet, preparation and distribution of information packages on the web, holding con specialized conferences by the organizations in charge of standards and standardization in the country can be the basis for raising the awareness of companies. Providing awards by organizations and bodies in charge of standardization, trade and industry to successful companies in applying standards can motivate other companies in determining their strategic goals based on standards. In addition, organizations in charge of standardization and national and local libraries should make standards available to applicants and interested parties at the lowest cost or even for free.

Holding short-term and specialized training courses and workshops are considered as one of the most effective ways to promote standards. Nowadays, considering the speed of development of information technology, the training courses and specialized working groups in virtual space for information sharing are identified as an effective solution in promoting and increasing the society's

awareness of the benefits of standards. Finally, providing continuous education to promote the standard culture at all educational levels from school to university especially for the young generation as future entrepreneurs of the country, can be considered as a successful and long-term investment method.

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An overview of the standard methods for hydrocarbon type detection of fuels

Nooshin Gholipour Zanjani [1*], Mohammadreza Moghaddam-manesh [1]

1. Petrochemistry Research Group, Chemistry and Petrochemistry Research Center, Standard Research Institute, Karaj, Iran.

Abstract

Generally, burning fossil fuels release large amounts of harmful air pollutants such as carbon dioxide and greenhouse gases into the air. Consequently, detection of feedstock's and petroleum products' specification could be essential to utilize the appropriate fuel. The detection of hydrocarbon types provides an insight to predict their performance. There are different gas chromatography based methods to identify the amount of aromatics, naphthenes, olefins and paraffins in the petroleum cuts. This investigation reviews the standard methods to compare the interfering substances, benefits and drawbacks of methods and their precision. Confirming the results of some methods need considering whole physical and chemical parameters as well as monitoring and verifying the method with higher sensitivity. Somewhat, the operative method should be selected regarding the precision of the method and considering the implications of inaccurate measurements. The identification of components contain some compromises and the best results are achievable just by conducting the optimum amounts of effective parameters, for instance the length and polarity of column or temperature programs in gas chromatography methods.

Keywords Hydrocarbon type, Gas Chromatography, Fuel, Gasoline.

1. Introduction

Fossil fuels, formed from the remains of animals and plants over millions of years, are one of the most important sources of energy supply in the world. Although they are very effective in climate change and there are alternative renewable energy resources, many countries utilize fossil fuels indiscriminately [1-4].

Brudzewski et al. utilized the results of gas chromatography (GC) and Fourier Transform Infrared spectroscopy (FTIR) of 45 gasoline samples with different qualities to predict the amount of octane number by an artificial intelligence approach [5]. They reported remarkable correlation between chemical composition of the gasoline samples and predicted values of the octane number to identify gasoline quality [5]. Gasoline, which is one of the fossil fuels, is used as an energy source in cars. Gasoline contains various organic compounds, and increasing or decreasing the percentage of its constituent compounds, besides polluting the environment, causes damage to the car [6, 7].

Huber et al. utilized two hydrocarbon type analysis methods by gas chromatograph equipped with a single capillary column and a valve-switched multi-column system. They used a Hewlett-Packard 5880A Gas Chromatograph with a flame ionization detector. Although the amounts of the individual components were detected by their method but they reported overlapping of olefins with other groups and hard separation of all the paraffins and naphthenes in the range of C9 and higher carbon numbers especially when analysing naphthas made from highly naphthenic

* Correspondence:
n.gholipour@standard.ac.ir

crude oils [8]. This separation was improved by adding a treated molecular sieve column in the multi-column valve-switched analyser. Their research had some limitations to use a second flame ionization detector (FID) and a second terminal [8].

There are some researches to determine physical properties including average molecular weight, density, carbon-to-hydrogen ratio and boiling range of petroleum associated condensate oil utilizing a GC equipped with capillary fused silica column and FID detector [9]. They considered the groups reference n-alkanes: n-C6 (C2–C9), n-C10 (C10–C13), and n-C14 (C14–C36), then detected the amount of density and molecular weight of the mixture of hydrocarbons considering the GC results and relative response factor calculated [9, 10].

By developing standards, the dangers of using fossil fuels can be avoided to some extent. In the field of developing standards related to fuel, Technical Committee 28 (Petroleum and related products, fuels and lubricants from natural or synthetic sources) of the International Organization for Standardization (ISO) develops the relevant standards. The main secretariat of this committee is in the Netherlands, and Iran is a participating member in this committee and plays an active role in drafting relevant standards. In addition, the American Society for Testing and Materials also compiles relevant standards in this field, many of which have global validity.

The specifications of gasoline were defined according to INSO 4904 and INSO 22920 [11, 12]. The detection of the accurate amount of total olefins, total aromatics and benzene is crucial to decide about the quality of this petroleum product. In international, regional and national standards, a practical limit has been defined for the mentioned parameters containing maximum total olefins of 18.0 % (V/V), maximum total aromatics of 35.0 % (V/V) and maximum benzene of 1.0 % (V/V). This review focus on the standard analytical methods to determine the hydrocarbon type regarding the amount of the precision and the potential interferences.

2. Measuring the hydrocarbon types by standard test methods

Many standards have been developed to measure the amount of olefins, aromatics and benzene in fuels, in this research the standard methods related to gasoline composition were studied.

2.1. Olefins

The relevant standards for measuring olefins are ISO 22854, EN 15553, ASTM D6839, ASTM D1319 and ASTM D6730[13-17]. ISO 22854 and ASTM D6839 are the similar methods which cover the quantitative determination of saturates, olefins (in the range from 0,40 % (V/V) to 26,85 % (V/V)), aromatics, and oxygenates in spark-ignition engine fuels and ethanol (E85) automotive fuel by multidimensional gas chromatography[14, 16]. Whole mentioned methods report hydrocarbon types by carbon number and as a total amount. Additionally, the benzene and toluene content, oxygenated compounds and the total oxygen content can be determined. The test methods can also be practical for having similar boiling ranges of hydrocarbons, such as naphthas and reformates [14, 16]. They are also applicable to automotive motor gasoline with total aromatics of 19,32 % (V/V) up to 46,29 % (V/V) and benzene content from 0,38 % (V/V) up to 1,98 % (V/V).

ASTM D1319 and BS EN 15553 similarly specify a fluorescent indicator adsorption method for the determination of 0,3 % (V/V) to 55 % (V/V) olefins and 5 % (V/V) to 99 % (V/V)aromatics in petroleum fractions that distil below 315 °C [13, 17]. These methods can apply to concentrations outside these ranges, but the precision has not been determined. This test method is applicable to full boiling range products. Their precision does not apply to petroleum fractions with narrow boiling ranges near the 315 °C limit. Because, such samples are not eluted properly, and results are erratic[13, 17].

ASTM D6730 covers the determination of individual hydrocarbon components of spark-ignition engine fuels and their mixtures containing oxygenate blends (MTBE, ETBE, ethanol, and so forth) with boiling ranges up to 225 °C[15]. Other light liquid hydrocarbon mixtures typically encountered in petroleum refining operations, such as blending stocks (naphthas, reformates, alkylates, and so forth) may also be analyzed; however, statistical data was obtained only with blended spark-ignition engine fuels [15]. This test method is applicable to samples containing less than 25 % by mass of olefins. Table 1 shows the precision reported for determination of olefins.

As it could be observed, the amount of repeatability for ISO 22854/ ASTM D6839 are less than ASTM D1319 that could be related to the base of methods. It could be concluded that the Fluorescent Indicator Adsorption method has more error in detection by overlapping the layers in the column chromatography.

2.2. Aromatics

The standard methods of ISO 22854, EN 15553, ASTM D6839, ASTM D1319, and ASTM D6730 could be similarly conducted to determine aromatic compounds [13-17]. Besides, some other methods of ASTM D5580 and D5986 are also recommended for determining aromatics [18, 19]. ASTM D5580 covers the determination of benzene, toluene, ethylbenzene, the xylenes, C9 and heavier

Table 1. The repeatability and reproducibility for measuring olefins

Standard	Repeatability (r)		Reproducibility (R)	
	For a range of data	Amount for X=15	For a range of data	Amount for X=15
ISO 22854	r=0.0185 X + 0.1415	0.4	R=0.1176 X + 0.5118	2.3
ASTM D6839	r=0.13 $X^{0.46}$	0.5	R=0.72 $X^{0.46}$	2.5
ASTM D1319	X=4-33: r=0.26 $X^{0.6}$	1.32	X=4-33: R=0.82$X^{0.6}$	4.16
ASTM D6730	Depends on the composition	Depends on the composition	Depends on the composition X=1.5:R=2.1	2.1
X is the mean of the two results in % (V/V) for one sample.				

Table 2. The repeatability and reproducibility for measuring total aromatics

Standard	Repeatability(r)		Reproducibility (R)	
	For a range of data	Amount for X=25	For a range of data	Amount for X=25
ISO 22854	0.0095 X + 0.1952	0.2	0.0450 X + 0.1384	1.3
ASTM D6839	0.012 (10 + X)	0.4	0.036(10 + X)	1.3
ASTM D1319	X=13-40 r= 1.3	1.3	X=13-40 R=3.7	3.7
ASTM 6730	Depends on the composition	Depends on the composition	Depends on the composition X=24.5: R=1.3	1.3
ASTM D5580	X= (16.34-49.07) r=0.0899($X^{0.5}$)	0.5	X= (16.34-49.07) R=0.2619($X^{0.5}$)	1.3
ASTM D5986	X=13-41: r= 0.55	0.55	X=13-41: R=1.65	1.65
X is the mean of the two results in % (V/V) for one sample.				

aromatics, and total aromatics (10 % to 80 %) in finished motor gasoline by gas chromatography[18]. In this method, the C8 aromatics, containing p-xylene and m-xylene co-elute while ethylbenzene and o-xylene are separated. Moreover, the C9 and heavier aromatics are determined as a single group[18].

ASTM D5986 covers the quantitative determination of oxygenates: methyl-t-butylether (MTBE), di-isopropyl ether (DIPE), ethyl-t-butylether (ETBE), t-amylmethyl ether (TAME), methanol (MeOH), ethanol (EtOH), 2-propanol (2-PrOH), t-butanol (t-BuOH), 1-propanol (1-PrOH), 2-butanol (2-BuOH), i-butanol (i-BuOH), 1-butanol (1-BuOH); benzene, toluene and C8–C12 aromatics, and total aromatics in finished motor gasoline by GC/FTIR [19]. Although this method could cover most of aromatics and oxygenate components, the connection of

Table 3. The repeatability and reproducibility for measuring benzene

Standard	Repeatability (r)		Reproducibility (R)	
	For a range of data	Amount for X=1.5	For a range of data	Amount for X=1.5
ISO 22854	X< 0.8: r=0.02 X≥ 0.8: r=0.0147 *X* + 0.0031	0.03	X< 0.8: R=0.04 X≥ 0.8: R=0.0777 *X* -0.025	0.09
ASTM D6839	r=0.019 $X^{1.6}$	0.04	R=0.053 $X^{1.6}$	0.10
ASTM D6730	r=0.036 *X*	0.05	R=0.09 *X*	0.13
ASTM D5580	X=0.11-1.5: r=0.0259($X^{0.64}$)	0.03	X=0.11-1.5: R=0.1087($X^{0.64}$)	0.14
ASTM D5986	X=0.1-2 r=0.0099(X+0.6824)	0.02	X=0.1-2 R=0.054(X+0.68)	0.12

X is the mean of the two results in % (*V/V*) for one sample.

GC and FTIR by a light-pipe could be complicated.
Table 2 depicts the range of repeatability and reproducibility of methods for aromatic detection. The amount of repeatability and reproducibility were determined while the total aromatics amount was 25%. The amount of repeatability and reproducibility for gas chromatography methods of ASTM D6839 and ASTM D 6730 were similar, although the amount of reproducibility of ASTM D5986 was more that could be related to the operating conditions such as type and length of column.

2.3. Benzene

Benzene as an aromatic component could be determined by ISO 22854, ASTM D6839, ASTM D5580, ASTM D5986, ASTM D6277 and EN 238 [14, 16, 18-21]. ASTM D6277 and EN 238 cover the determination of the percentage of benzene in spark-ignition engine fuels utilizing infrared spectroscopy [20, 21]. According to table 3 the amount of the repeatability and reproducibility for measuring benzene (while X=1.5%V/V) are different, therefore the selection of methods could be performed regarding the precision on demand.
Table 4 depicts the detection limit of the methods to measure the amount of total olefins, benzene, total aromatics and the boiling range of components could be separated by each one.
To detect the linearity of the mentioned chromatography methods, the peak areas of an internal standard containing components such as benzene and toluene are checked regarding the actual amount of each constituent[18]. Some error are regularly encountered due to co-elution and a deficiency in components detection. Relative error is usually determined by the ratio of the difference between the real amount of a component concentration and detected concentration to its real one. On the other hand, a linear split injection is considered as a requirement to identify constituents [15]. Optimum column efficiency and detector linearity are affected by the actual chromatographed sample size[18].
In ASTM D6730, the relative error or the splitter linearity range of (3% or less) was reported while the method was conducted according to the recommended conditions of column, temperature and flow[15].

3. Interferences in gas chromatography

Common sources of error include instrumental, environmental, procedural, and human. All of these errors can be either random or systematic. Instrumental error happens when the instruments being used are inaccurate, such as a balance that does not work. The main sources of error are contamination, measurement errors and mechanical/instrument errors such as fluctuations of inlet pressure, outlet pressure, detector temperature, column temperature and sample size. In addition, errors can come from the noise and from the measurement itself. Improving accuracy and precision of the gas chromatographic system

Table 4. Comparison of the detection limit and the linearity range of the methods

Standard		components			Boiling range of materials
		Total Olefins	Benzene	Total aromatics	
ASTM D6839/ ISO 22854	Low Detection limit % (V/V)	1.5	0.01	20	Maximum 215 °C
	Linearity range % (V/V)	1.5-30	0.01- 2	20-50	
ASTM D1319/ BS EN 15553	Low Detection limit % (V/V)	0.3	Not detect	5	Maximum 315°C
	Linearity range % (V/V)	0.3 – 55	Not detect	5-99	
ASTM D6730	Detection limit % by mass	0.01	0.01	15	Maximum 225 °C
	Linearity range % by mass	0.01-25	0.01-30	15-50	
ASTM D5580	Low Detection limit % (V/V)	Not applicable	0.1	10	Not reported
	Linearity range % (V/V)	Not applicable	0.1 – 5	10- 80	

depends on the nature of the chemicals and hardware factors such as temperature dependence of flow controllers and sample fractionation, both prior to and during injection. The precision attainable could be affected by the type of injection with Indium tube sample injection or with syringe injection [22].

The impurity of the carrier gas could be a potential contaminant which should be reduced in order to achieve reproducible results and to extend the lifetime of GC columns [23].

Purity of gases, ranging from 99.996% (4.6 grades) to 99.99999% (7.0 grades) purity, that are used as carrier gas in gas chromatography or as calibration standard are important. Checking the impurities of gas by gas chromatography had an acceptable results for the analysis of various matrix of materials [24].

Mechanism of Interferences for gas chromatography are important especially the adequate separation of the compounds prior to mass spectrometry analysis or other detectors are essential to avoid the same mass spectrum for two components[25]. The ionization efficiency of the target compound may be affected by electron impact (EI) ionization. Besides, according to researches, many of the spectral interferences can be avoided by using high MS resolutions (35 000 or better)[26]. The concentration ratio of the coeluting compounds and/or the number of quantitation ions are effective on partially overlapping mass spectral profiles [27].

Mostly, the determination of the total amount of saturates, olefins, and aromatics in petroleum fractions is significant in illustrating the quality of gasoline. Table 4 shows the benefits and drawbacks of the standard methods to

Table 5. Comparison of the methods for hydrocarbon type detection of gasoline

Standard	Method	Benzene	Total Aromatics	Total olefins	Interferes/ drawbacks
ASTM D1319/ ISO3837/ INSO8403	Adsorption Columns	applicable	applicable	applicable	dark-color components may interfere in recognizing the chromatographic bands
ASTM D6730/ INSO22888	GC	applicable	applicable	applicable	- olefins above C7 may be co-eluted, particularly if blending components or their higher boiling cuts such as those derived from fluid catalytic cracking (FCC) are analyzed, and the total olefin content may not be accurate.
ASTM D6839/ ISO22854/ INSO19324	GC	applicable	applicable	applicable	- Method doesn't able to determine individual hydrocarbon components except benzene. -There are a relative bias section for total olefins
ASTM D5580/ INSO17268	GC	applicable	applicable	Not applicable	-Nonaromatic with a boiling point greater than *n*-dodecane may cause interferences with the determination of the C9 and heavier aromatics. - *p*-xylene and *m*-xylene co-elute. -The C9 and heavier aromatics will be detected as a single group. -Not applicable for olefins
ASTM D5986	GC/FTIR	applicable	applicable	Not applicable	-Not applicable for olefins

detect hydrocarbon types of gasoline. As it could be observed, some methods aren't applicable determining olefin amount such as ASTM D5986 and ASTM D5580 [18, 19]. On the other hands, the amount of olefins determined by ASTM D6839 and ASTM D6730 need to be assessed by calibration of the GC and certified materials [14, 15]. The column temperature program rate and the length of the packed precolumn are very important to achieve enough resolution by ASTM D6730. For instance, to achieve a suitable separation of p-xylene and 2,3-dimethylheptane, the hold temperature should be lowered from 50 °C to 48 °C (figure 1.a)[15]. On the other hand, the column temperature program rate should be enough to distinct 1-methylnaphthalene and tridecane (figure 1.b). If the resolution is incomplete, this rate may be adjusted to run sufficient separation, for example it could be decreased from 1.5° ⁄min to 0.1 ° ⁄min[15]. At all, the change of temperature program, the length of the columns, the flow of carrier gas, the amount of injected materials are some of effective parameters to achieve suitable separation.

Today, some software such as Dragon could determine this physical properties of petroleum cuts using the composition of the sample according GC results considering the properties of pure materials such as density and

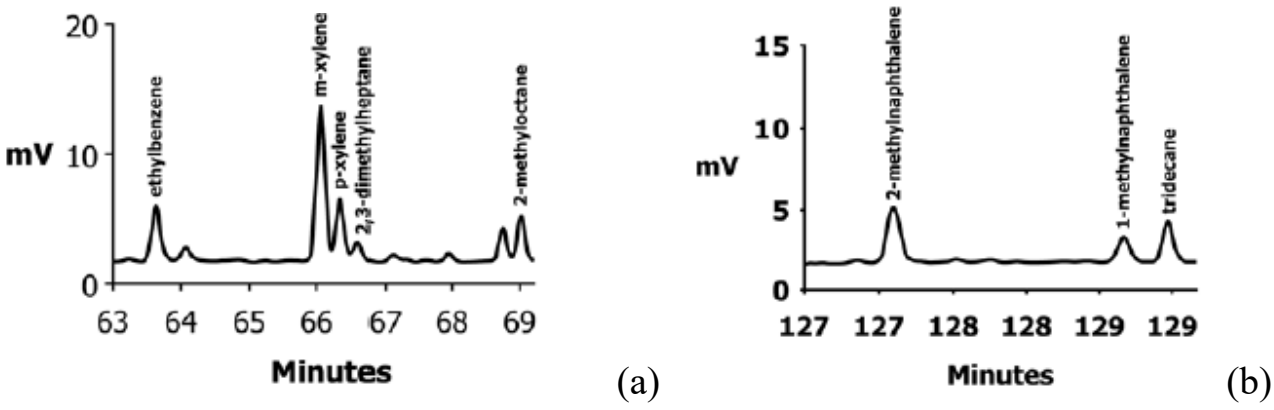

Fig 1. The separation of (a) p-xylene/2,3-dimethylheptane and (b) 1-methylnaphthalene/tridecane[15]

molecular weight. The input information in this types of software (including the amount of density or molecular weight and boiling point of each component) is imperative to achieve reliable results.

4. Conclusion

This document compares the methodologies for the hydrocarbon type detection utilizing standard methods which most of them are gas chromatography based. Totally, conducting the analysis of trace-level impurities in petroleum products by gas chromatography technique could be a real challenge. Most of methods give the quantitative determination of paraffins, olefins, naphthenes and aromatics in total as well as by carbon-number. Variability in measurements made on the same subject could be related to different parameters and considering associated repeatability or reproducibility could be significant for decision about the acceptable results. Therefore, the proposed amount of repeatability and reproducibility of the available methods were discussed and the interferences in the detection of components were described. Besides, the advantages and limitations of methods were discussed. Changing some parameters such as the rate of temperature program and the types and length of the columns, type of detector and split ratio are effective to attain the acceptable the relative error or the splitter linearity range. In the main, defining analytes and effective parameters are essential for developing a successful method.

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Declarations

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Consent for publication
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Original Open Access

Designing, Programming and Feasibility study of a Paddle Wavemaker to increase quality and decrease production costs

Karim Kenarkoohi [1], Ruhollah Jafari [2*], Mostafa Tamtaji [3]

1. Department of Physics, Malek Ashtar University of Technology, Tehran, Iran.
2. Department of English Language, Humanities Faculty, Shahid Rajaee Teacher Training University.
3. Department of Service Management and Technology Development, Allameh Tabataba'i University, Tehran, Iran.

Abstract

Quality needs to be included in the core of the manufactured products; it should not be left to the after-production inspection. Hence this paper aims at changing the structure of the wavemakers which are mainly mechanical to electronically controlled devices from the beginning of the design process in order to lead to increased quality. Besides, to increase the accuracy of the produced waves, servomotor which is better controlled is used instead of stepper motors. Designing a marine structure requires marine laboratories and model testing. In such laboratories, a device called wavemaker is needed to create and model sea waves. In this project, first samples of existing water flume and wavemaker are analyzed. Then basic information about design and construction is extracted. Afterward, the initial outline for the wavemaker is proposed and detailed design is done. The initial goal is to build a scale-appropriate model for use in the laboratory that could generate regular waves with maximum amplitude. This requires a servomotor and ball screw system. Albeit such a scheme was considered so that it would be similar to the original system, which could later, produce irregular waves with the desired spectrum; otherwise, in the case of using other systems, which are much simpler and cheaper than the servo system, we would be able to produce regular waves. Some programs are written to create a regular wave and an appropriate set of controls for generating a regular and irregular wave are created to prepare the system for producing irregular waves, if necessary. Although due to the limitation of the dimensions we might not be able to generate such waves in the laboratory, it can be used in the integrated water flume to generate irregular waves. Given the range of the desired waves, the best system for producing irregular and regular a wave in flume is the paddle wavemaker for which the designs are provided.

Keywords Sea wave modeling, Paddle wavemaker, Servomotor

Introduction

It is known that "the only criterion for measuring performance is the cost of quality" [1]. The only acceptable standard is zero defect work. In fact, zero defect production means to do the job right from the start. Therefore, this paper is aimed at designing correctly and using electrical commands instead of the mechanical ones to reduce production costs from the start of the designing, in other words to increase the quality. To do so, servomotors are chosen because they enjoy the capability of electrical sig-

* Correspondence:
Ruhollahj@sru.ac.ir

nals reception. The servomotor is designed so as to have built-in microcontrollers that can do a great deal of tasks using very simple commands. In addition, using servomotors can lead to reduction of size, noise and contamination which are dire burdens of mechanical systems.
Commonly manufactured wave generators are paddle wavemakers and Piston wavemakers [2] either of which can generate regular and irregular waves. They selection is proportionate with water depth. Since it is easier to analyze and theoretically explain the relations of regular waves compared to irregular waves, the waves are usually considered regular which later combine to yield irregular waves [3]. The piston wavemaker generates concurrent and roughly similar waves in the water flume [4], [5]. In practice, this kind of wavemaker is used in flumes where shallow water tests are implemented because there is a rather weak flow of water resulted from the generated waves. However, the rotation center in the paddle or hinged wavemaker is fixed such that it is mainly used in deep water tests because it generates no flow at the bottom of the flume [6]. Therefore, as the waves generated by the paddle/hinged wavemaker are very similar to the deep-water waves and deep water is much more similar to the real situations, this kind of wavemaker will produce better results (see figure 1).

2. Background Research

The development of an effective mathematical model of a control system used in an irregular wave maker-hinged flap type, featuring active wave reflection compensation is discussed in the paper titled "a wave maker with active reflected wave compensation system" by Fábio Nascimento et al. (2002) [7]. The writers conclude that 'a very efficient absorbing scheme can be developed for a wide range of reflected wave frequencies. Also, absorbing features can be easily implemented with relatively low hardware cost, on a wave-maker with a computer based closed loop controller'.
A new active absorption system based on wave gauges mounted on the moving paddle was presented by T.Lykke Anderson et al. (2016) [8] in the paper titled "A new active absorption system and its performance to linear and non-linear waves" .The active absorption system was extended to cases where the wave gauge had a gap to the paddle face. Such gap could be used to compensate wavemaker systems with large control delay. The active absorption transfer function was approximated by a FIR filter which led to similar or slightly better performance than IIR filters applied in earlier studies.
S.H. Salter (1981) in the paper "Absorbing Wave-Makers and Wide Tanks" [9] which was presented in *The Conference on Directional Wave Spectra Application* stated that' displacement of a wave-maker is a bad signal to use for control. The size of wave created is affected by reflections and waves from adjacent units. Several techniques can be used to absorb unwanted waves, but force measurement is attractive on practical grounds. Absorption makes for good stability. Asymmetric wave-makers save power and the cost of power control elements. Asymmetry can be achieved for piston displacers for shallow water, but flaps are good for deep water. Directional spectra can be generated by the superposition of discrete monochromatic wave fronts. Provided that sufficient fronts are used it is difficult to distinguish the sea state from that of a continuous spectrum. The discrete method enables the controlled composition of abnormal seas.
The paper "Closed-loop Discrete-time Control of a Hinged Wavemaker" by S.E. Hodge and D.B. Chechas (1988) developed a control strategy for the discrete-time control of a particular wave generation system using conventional discrete-time control theory [4]. The main difference from conventional discrete-time control theory in their work was the use of a long duration discrete timestep between successive controller actions. They showed that an effective stability analysis is possible and useful for determining control parameters assuming that for each frequency in the desired wave spectrum, there is a unique controller gain combination as opposed to using one gain combination for all frequencies.
M.H. Patel and P.A. Ionnaou (1980) in the paper "Comparative Performance Study of Paddle and Wedge-Type Wave Generators" carefully measured the wave generating performance of a paddle- and wedge-type wave generator and compared with predictions from linear theory [6]. They concluded, despite the fact that a good agreement between theory and experiment is obtained, the tests highlight the importance of avoiding both wave generator edge leakage and wave reflection effects if optimum performance is required of the generators when installed in a wave testing tank. Finally, they suggested alternative methods of overcoming both of these difficulties.
The paper "Dynamic covariance Equations for hinged wavemakers" by Robert T. Hudspeth and John W. Leonard (1980) verified experimentally the squared modulus of the theoretical dimensionless frequency response functions for the wavemaker stroke spectrum and for the wavemaker hydrodynamic pressure moment spectrum of the hinged wavemakers [5],[10]. The writers showed that 'the use of the theoretical dimensionless frequency response functions for the stochastic design of hinged wavemakers of variable-draft now appears to be experimentally justified by these unique measurements of hydrodynamic pressure moment spectra on hinged wavemakers.
W.M. Kusumawinahyu, et al., in the paper titled "lin-

ear theory for single and double flap wavemakers" concerned themselves with deterministic wave generation in a hydrodynamic laboratory [11]. They developed a linear wavemaker theory based on the fully dispersive water wave equations and considered both single-flap and double-flap wavemakers. The velocity potential and surface wave elevation were derived and the relation between the propagating wave height and wavemaker stroke was formulated. This formulation was then used to find how to operate the wavemaker in an efficient way to generate the desired propagating waves with minimal disturbances near the wavemaker.

3. Paddle/hinged wavemaker equations

Paddle wavemaker performs very well in deeper tanks. In this type of wavemaker the wave plate is hinged from one side to the bottom of the tank and the other side is moved which eventually results in the wave generation. Like the piston wavemaker, in order to achieve a better performance, the sealing between the wave plate and the walls has to be observed. Displacement velocity of the wave plate at different distances from the water line is very close to the velocity of the water particles beneath the wave crest and the wave trough from the water line to water depth, which is why this type of wavemaker performs well in deeper tanks. Figure 2 shows an overview of the paddle wavemaker and how a wave is created in the paddle/hinged wavemaker.

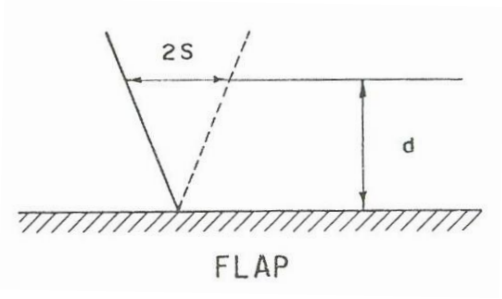

Fig 1. The paddle/hinged wavemaker [11]

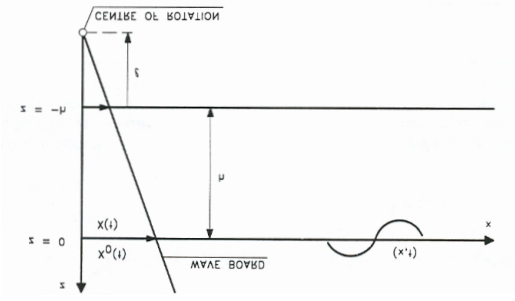

Fig 2. How to create a wave in a paddle wavemaker [6]

The following relationship expresses the wave height-to-stroke ratio of a paddle wavemaker system resulting from the Laplace's equation.

$$\frac{H}{S}=\frac{4\sinh kh}{\sinh 2kh+2kh}\left[\sinh kh+\frac{(1-\cosh kh)}{kh}\right]$$

In this relationship, it is assumed that the wave plate has been hinged at the bottom of the flume and ***h*** is the depth of the flume.

The following relationship describes the wave plate motion equation in the paddle wavemaker [12].

$$X(t)=\frac{H}{2m_1}\sin\sigma t+\frac{H^2}{16h}\left(\frac{3\cosh kh}{\sinh^3 kh}-\frac{2}{m_1}\right)\sin 2\sigma t$$

$$m_1=\frac{4\sinh kh}{\sinh 2kh+2kh}\left[\sinh kh+\frac{(1-\cosh kh)}{kh}\right]$$

Where:

X: hinge location, **H**: wave height, σ: Frequency, **t**: time, ***h***: flume depth, **k**: wave number and equal to $\frac{2\pi}{L}$ where L is wave number

Having the wave plane displacement equation in the paddle wavemaker clarified, the speed and spatial position of the wave plate can be controlled with good accuracy.

4. Design details

Since the paddle wavemaker is used in deep water, **d/λ** must first be calculated, which should be greater than 0.5 for deep water to meet the deep-water condition. Given that the depth of the flume is known, **λ** can be calculated [12], [3].

Now the ratio for each force could be calculated. Since **λ** and **H** are known in each force, by obtaining the **λ** and $\frac{H_1}{H_2}=\lambda_1/\lambda_2$, the ratio $\frac{H_1}{H_2}$ and as a result, the model ratio is obtained. H_2 is also obtained.

For example, for a model with force 4 and depth 0.7 m, the following equation exists:

$$H_1=0.77\text{m}\ ,\ \lambda_1=25\text{m}$$

And from the deep-water relationship we have:

$$\frac{d}{\lambda}>0.5\Rightarrow\lambda<\frac{\text{d}}{0.5}=\frac{0.7}{0.5}=1.4\Rightarrow\lambda_{\max}=1.4\text{m}$$

$$\frac{0.77}{H_2}=\frac{25}{1.4}=17.86\Rightarrow H_2=0.043m=4.3cm$$

$$T=\sqrt{\frac{\lambda}{1.56}}=0.95\text{s}\Rightarrow\text{f}=1.06\text{Hz}$$

$$\frac{\mathrm{H}}{\mathrm{S}} = \frac{\pi}{\lambda} d = \frac{\pi}{1.4} * 0.7 = 1.57 \Rightarrow \mathrm{S} = \frac{\mathrm{H}}{1.57} = .027\mathrm{m} = 2.7\mathrm{cm}$$

To find the maximum power required, a condition needs to be considered where a wave with the maximum amplitude is generated. In this case, an additional condition must also be considered which is the wave steepness condition or $\frac{\mathrm{H}}{\lambda} < \frac{1}{7} = 0.14$ [5]. Hence, to calculate the maximum height and velocity, one must calculate **λ** from the above relation with respect to the depth and calculate the time **T** using the equation and then obtain the frequency. In this case, the value of **H** should be calculated using the wave steepness condition or $\frac{\mathrm{H}}{\lambda} < \frac{1}{7} = 0.14$ which is the maximum wave height and can be used to calculate the stroke. Using the existing equations, one can calculate the wave plane velocity and its acceleration, as well as the applied forces and the desired power.

For example, for the desired flume in the laboratory with a water depth of 0.7 we have:

$$\frac{d}{\lambda} > 0.5 \Rightarrow \lambda < \frac{\mathrm{d}}{0.5} = \frac{0.7}{0.5} = 1.4 \Rightarrow \lambda_{\max} = 1.4\mathrm{m}$$

$$T = \sqrt{\frac{\lambda}{1.56}} = 0.95\mathrm{s} \Rightarrow \mathrm{f} = 1.06\mathrm{Hz}$$

$$\frac{\mathrm{H}}{\lambda} < \frac{1}{7} = 0.14 \Rightarrow \mathrm{H} < \frac{1}{7} * \lambda = \frac{1.4}{7} = 0.2m$$

Considering the deep-water assumptions, the plate motion relations can be simplified as follows:

$$\frac{H}{\mathrm{S}} = \frac{\pi \mathrm{d}}{\lambda} \Rightarrow \mathrm{S} = \frac{\mathrm{H}\lambda}{\pi \mathrm{d}} = \frac{0.2 * 1.4}{\pi * 0.7} = 0.13\mathrm{m} \Rightarrow \mathrm{v}_{\max} = 2\pi \mathrm{fS} = 2 * \pi * 1.06 * 0.13 \Rightarrow$$

$$\mathrm{v}_{\max} = 0.86 m/s$$

$$\mathrm{a}_{\max} = 4\mathrm{S}\pi^2\mathrm{f}^2 = 4 * 0.13 * 9.87 * 1.12 = 5.77$$

The mass of water displaced, and the metal used is equal to:

$$m_w = \rho(S * \mathrm{d} * 0.5) = 1000 * 0.13 * 0.7 * 0.5 = 45.5\mathrm{kg}$$

Assuming that the density of metal used is 10 times the water and has a thickness of 3 mm, and also the width of the flume is 1.2m, the metal mass is obtained as follows:

$$m_m = \rho(w * \mathrm{d} * 0.003) = 10000 * 1.2 * 0.7 * 0.003 = 25.2\mathrm{kg}$$

Therefore, the total force is calculated as follows whereby the power can also be calculated:

$$F_{\max} = \mathrm{m} * \mathrm{a}_{\max} = 70.7 * 5.77 = 408$$

$$P_{\max} = \mathrm{v}_{\max} * \mathrm{F}_{\max} = 0.86 * 408 = 350\mathrm{watt}$$

The MRJ3A 400watt servomotor system was selected given the calculated power [13], [14], [15], [16], however, in practice, the required power may be less than this amount. The overall shape of the wavemaker using the servomotor should be designed as follows, where its different parts will be described (figure 3.).

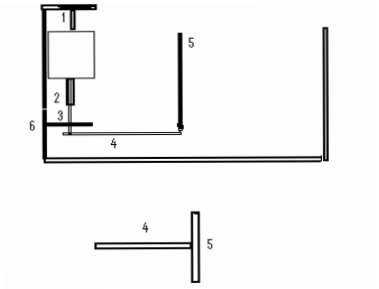

Fig 3. The overal shape of wavemaker using servomotor

Part 1 in the figure shows the servomotor and the relevant connections to fix it at the desired location. Part 2 shows the coupling required to attach the servomotor to the ball screw. Part 3 is the required ball screw with an appropriate step to move the wave plane up or down. This part converts the rotational motions of the motor into reciprocating linear motions through the systems in part 6 which is fixed-connected. The number of desired rotations in this section is limited by the ball screw step. Part 4 is a rod that connects the wavemaker plate to the ball screw system. Finally, part 5 is the wavemaker plate.

The most important point that must be considered with regards to servomotor specifications is that every 2000-pulse is considered one cycle for the servomotor. This is essential when programming to control the servomotor [13], [14], [15], [16].

Requirements for connecting the servomotor to the computer, as well as the specifications of the computer required, and how to connect it to the computer, and how to install the software, are given in appendix.

To program the servomotor internal microcontroller, the following commands are needed that will be explained, albeit care needs to be exercised that the program can be up to 300 lines:

SPN: Indicates the servomotor speed per minute, which is 6000 rpm for the servomotor in question. This value is displayed by the software as error if it is exceeded.

STC: is used to adjust the servomotor acceleration. Since the wave plane should not be displaced by impact, this option is used to move the wave plane in sinusoidal form. In fact, this option determines the time required to reach the selected speed. The value of this option is between 0 and 50,000 milliseconds. The larger the selected number, the lesser the acceleration to reach the selected value.

MOV: This command actually indicates the amount of servomotor displacement that can range between -9999999 to 9999999 pulses. If a counterclockwise rotation is desired, no sign is needed and if the clockwise rotation is needed, a

negative sign is required. Since the wave plane needs to have a reciprocal motion against the middle point, positive and negative motions should be used in the program. Also notice should be given that by setting the required parameters in this case, every 2000 pulse is considered as one cycle.
SYNC: Using this command, the servomotor will wait for an external signal to start operating. The signals that can be used for MRJ3A servomotors are as follows: SON, LSP, LSN, TL, PC, RES, CR, and given that these signals were manually grounded, they were not used in the program.
TIM: This command specifies the time between two consecutive commands, and its value is between 0 and 50 seconds. If irregular waves are to be generated, this command is used for creating a gap between the regular output waves that cause the final irregular wave.
TIMES: This command displays the number of times a program has been executed. In the software booklet, the number of times a program can run is from 1 to 99, but with practical tests specified, there is no limit to that, and the program can be repeated to any desired number.
STOP: It is used to stop the program and does not need to be used in cases where the reiteration of the program is desired.
Various programs have been written that can be used to generate regular waves. The following program is written to produce a wave with a certain specification (amplitude≤ than 50 Cm) :
TIMES(10), SPN(6000), STC(1000), MOV(55), SPN(6000), STC(2000), MOV(55), SPN(6000), STC(3000), MOV(55) ,SPN(6000), STC(4000), MOV(55), SPN(6000), STC(5000), MOV(55), SPN(6000),STC(1000),MOV(-55),SPN(6000),STC(2000), MOV(-55), SPN(6000), STC(3000), MOV(-55), SPN(6000), STC(4000), MOV(-55), SPN(6000), STC(5000), MOV(-55), STOP,

5. Conclusions

In this work, first a brief review of the piston and paddle/hinged wavemakers is presented. Then the design and feasibility study of the hinged wavemaker is addressed; to make a hinged wavemaker, a 400watt servomotor is utilized in or to generate waves with desired amplitudes. The servomotor is preferred over stepper motor in that it creates better results. The required programs are written with an appropriate microcontroller in such a way that a regular set of waves can be generated. The findings of this work could be utilized for making paddle wavemaker used in water channels.

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Book Review Open Access

Book: Internal Quality Control in Laboratory

Akram Beigi [1*]

1. Department of Computer Engineering, Shahid Rajaee Teacher Training University, Tehran, Iran.

Abstract

Quality control plays a crucial role in various domains, including production, services, and testing. The principles and techniques of quality control can be applied not only to product manufacturing but also to the service sector. One significant area where quality control is vital is in the testing and assessment of standard conformity. In particular, quality control in laboratories holds immense importance. In this review, we will provide an overview and discuss a recently published book titled: "Internal quality control in laboratory". The review will focus on the book's content, its application in different areas, and the innovative aspects it presents. The book itself is concise and comprehensive, offering a self-contained resource. It introduces key concepts from statistical quality control, eliminating the need for readers to refer to prerequisite textbooks. The book's strengths lie in its clarity, simplicity, and brevity, making it accessible for understanding quality control concepts and applying them within a laboratory setting. Additionally, the book includes numerous illustrative numerical examples, which further enhances its usefulness. The book targets quality control personnel in conformity assessment laboratories. However, it is also useful for general audiences with engineering and statistics background. The book covers basic needs of the targeted audience and deemed to be a good starting point for a quality control profession.

Keywords Management System, Internal Quality Control, Laboratory, ISO/IEC 17025

1. Introduction

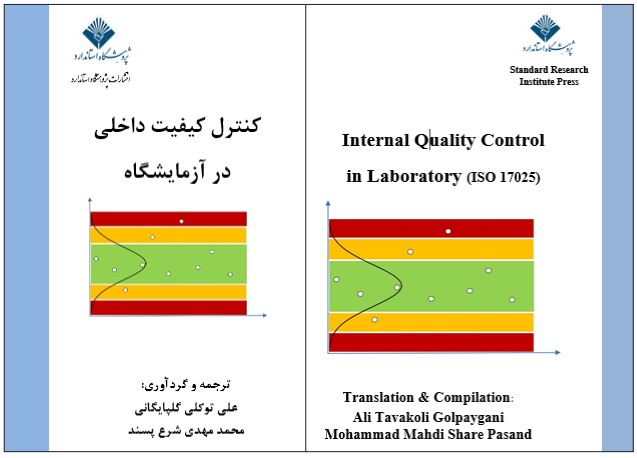
Quality control is an important subject in production, service and test areas. Techniques of quality control are applicable to service sector as well as product manufacturing. An important service which is subject to quality control, is the testing and standard conformity assessment. Quality control in laboratories is of utmost importance. International standards in the field of laboratory management (e.g., ISO/IEC 17025) require a quality control scheme to ensure continuous improvement of the laboratory services. The laboratories must hold accreditation in order to be deemed technically competent and ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories is the main standard used by testing and calibration laboratories.

Any test or calibration laboratory shall have a procedure for monitoring the validity of results. The resulting data shall be recorded in such a way that trends are detectable and, where practicable, statistical techniques shall be applied to review the results. This monitoring shall be planned and reviewed and then referring to both internal quality control and proficiency testing, data from monitoring activities shall be analyzed, used to control and, if applicable, improve the laboratory's activities. If the results of the analysis of data from monitoring activities are found to be outside pre-defined criteria, appropriate action shall be taken to prevent incorrect results from being reported. The ultimate aim of a laboratory quality control program is to ensure that the test/ measurement results comply to established performance criteria including the

* Correspondence:
akrambeigi@sru.ac.ir

reproducibility and repeatability of test results. The laboratory quality control program ensures that the results and measurements are reliable and have errors within the prespecified bounds.

This book review is dedicated to introduce and discuss the recently published book entitled as " Internal quality control in laboratory".



Book description

The bibliographical information of the book are as follows: Tavakoli Golpaygani, Ali and Mohammad Mahdi Share Pasand, Internal Quality Control in Laboratory, Standard Research Institute Press, Nov. 2023, Karaj, Iran.

The book is published in Persian. The publisher; Standards Research Institute press, publishes applied and theoretical books relevant to the fields of testing, quality control, standardization and conformity assessment. Authors have more than a decade experience in conformity assessment laboratories and have been collaborating in laboratory accreditation for ISO/IEC 17025 compliance [2].

The book contains 123 pages, 14 figures, 5 tables and more than 15 numerical examples discussing the derivation of statistical figures required for laboratory quality control in real world applications.

Significance of the subject

Quality control in laboratories is a very essential concern. Chemical and biological laboratories are playing vital roles in the society. For example, a physician many prescribe a certain dose of a drug based on a report on the patient's blood test from a diagnostic laboratory. The laboratory result should be reliable and precise. A laboratory willing to attain reliable (repeatable and reproducible) results and maintain a high statue with regard to customer satisfaction, will need to implement and monitor an effective internal quality control program to regularly check its test and measurement procedures. For a quality manager working at such a laboratory, it is crucial to understand and effectively practice the concepts and methods of internal quality control descried in this book.

Readership

"Internal Quality Control in Laboratory" is easy to follow. Nevertheless, some parts of the 4th chapter, may be challenging for those readers not familiar with statistical quality control techniques. The target audience of the book are those laboratory experts who are mostly focused on technical aspects of their works but need to have a good practical skill to do quality control and statistical calculations for their own. An expert quality personnel or a well-educated mathematician/ engineer in the field of statistical quality control may find the book too simple. These readers, however, may find chapters two and three insightful. Laboratory managers will also find the contents useful since they need to understand these concepts before scheduling their programs.

Coverage and comprehensiveness

"Internal Quality Control in Laboratory" covered many aspects and issues required by a quality personnel working or aiming to work at a conformity assessment laboratory. However, this book should be considered a handy starting point which emphasizes on the basics and gives simple treatments for most of daily problems in laboratory quality control. However, this book is not a comprehensive nor an elaborate treatment of the subject. For more details on the mathematical methods, advanced subjects and recent findings, the reader should consult many existing text books including [4], [5] and [6].

Structure and organization

The book is brief and self-contained. Some concepts from statistical quality control are introduced so the reader does not need to refer to any pre-requisite text books. In the following, the main contents of each chapter is given:

The first chapter is dedicated to terms and definitions. Though most of the definitions are drawn from international standards vocabulary, some definitions are rephrased to better convey the meaning of each term and facilitate its understanding for readers.

The second chapter discusses quality control, control charts (x-charts and r-charts), within-laboratory reproducibility, repeatability, measurement uncertainty, bias and different control samples. Methods and recommendations to derive target and alarm control limits are discussed as well. Important guidelines are then given to plan a quality control system and perform daily/ routine as well as long-term evaluations of the gathered data.

The third chapter deals with the proficiency testing technique. The proficiency testing is the mostly accepted

method of inter-laboratory evaluation [3]. Although proficiency testing is an inter-laboratory activity to evaluate and grade participating laboratories as per ISO/IEC 17065, it can also be used by the quality personnel to examine and re-define internal quality control programs. Therefore, this book also introduced and briefly discussed the most important statistical methods used in proficiency testing. This chapter tries to equip the reader with the essential elements of a comprehensive internal quality control program.

The fourth chapter discusses in detail, statistical methods and formulae frequently used in data evaluation for internal quality control. Outlier detection, conformity (similarity) evaluation (for two sets of measurements), estimation of pooled mean and variance, estimation of the mean and variance of each data set and variance conformity tests are discussed with numerical examples. In this chapter, important statistical tests including Students' T, Fishers', Cochran's and David's are briefly introduced and used in application-oriented examples.

The book contains six appendices. The first appendix is a useful complete example of a quality control test. Other appendices provide data tables of important probability density functions and statistical tests. Appendices 2 and 3 give Fishers' test upper limits for 95% and 99% confidence intervals, respectively. Appendices 4 and 5 contain Chi-square and Students' T distribution probabilities. Appendix 6 contains confidence intervals for different sample volumes and coverage factors of a Gaussian distribution.

Novelty and Innovation

The strength points of the book are its clarity, simplicity and brevity. It has made it simple to understand quality control concepts and utilized them in a laboratory. The book contains several illustrative numerical examples which is also an advantage.

Conclusion

In this book review, a recently published book titled: "Internal Quality Control in Laboratory" is introduced and reviewed. Content, chapters, practicality and innovative aspects of the book are briefly discussed. The book provides a concise and comprehensive resource that covers the book's content, application areas, and innovative aspects. With its strengths lying in clarity, simplicity, and brevity, the book effectively aids in understanding quality control concepts and their practical implementation within laboratory environments.

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Declarations

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