**Towards blockchain-based hospital waste management systems; applications and future trends**

## Highlights

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A comprehensive review on state-of-the-art of hospital waste management is presented.

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Blockchain-based solutions for challenges of hospital waste management are stated.

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Blockchain-based architecture for industrial sewage management is expressed.

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The current limitations and emerging research trends are enlightened.

## Abstract

Effective hospital waste management (HWM) has become a significant environmental and green healthcare domain issue. In this regard, recent outstanding technological advances in artificial intelligence, the Internet of Things, and block chain technology have made significant contributions in solving environmental challenges. This study aims to address how blockchain technology would meet the requirements of HWM. Hence, a comprehensive systematic literature review is done to identify and critically appraise blockchain applications in the field of study. These applications are classified into waste generation, waste separation and packaging, waste storage containers, waste collection, temporary waste storage area, waste treatment, off-site and on-site transport of waste, waste disposal, hospital staffs training, waste management regulations, hospital sewage system, energy, and waste recycling and reuse. Moreover, each cluster's current limitations and challenges to enlighten the existing research gaps and clarify future trends are addressed. The findings of this study would be helpful for researchers interested in green healthcare, specifically drug, pharmaceutical, and HWM and related fields.

## Graphical abstract

Blockchain based Environmental protection platform

## Introduction

Due to the increasing generation of waste around the world (Amariglio and Depaoli, 2021; Pluskal et al., 2021), the protection of human civilization against the threatening effects of manufactured waste has become one of the most crucial issues for researchers (Banerjee et al., 2019). Waste is defined as any solid, liquid, or gas (Bhardwaj & Kumar, 2021) discarded or residual used raw material that remained (Himabindu et al., 2015) on the ground or into the air (Rajan et al., 2019). In numerous studies, waste has been considered a significant problem around the globe (Bartolacci et al., 2019), which in addition to affecting environmental issues (Lestari and Trihadiningrum, 2019; Rautela et al., 2021; Xu et al., 2020), it has economic issues (De Feo et al., 2019; Ko et al., 2020; D. Lu et al., 2021) and human health problems (Ádám et al., 2021; Addo et al., 2017; Gangwar et al., 2019). Due to the population growth and increasing human waste production (Richter et al., 2021; Saladié, 2016; Xiao et al., 2020) as well as its destructive effects, waste management faces many challenges and complexities (Christensen et al., 2020).

Waste management is defined as the ability to deal with waste generated and eliminate its destructive effects on the environment, economy, human health, etc. (Ishtiaq et al., 2018). Waste management has been considered in various industries, such as healthcare (Zamparas et al., 2019). Numerous researchers have considered waste management in health, treatment, medicine, and hospitals (Awodele et al., 2016; Harding et al., 2021). Waste management in hospitals has become a severe threat to the health of the community (Çakmak Barsbay, 2020; Omoleke et al., 2021; Srivastava and Rawal, 2021) as well as those working in the hospital (Agrawal et al., 2021) due to its inherent toxic and infectious nature (Behnam et al., 2020). Hospital waste is considered any waste generated during the diagnosis, treatment, immunization of humans or animals. It includes blood-stained bandages, laboratory utensils (Alagöz and Kocasoy, 2008), disposable gloves and surgical instruments, needles, tape, etc. (Basak et al., 2019). Waste generated in hospitals mainly consists of two types of hazardous (Akpan and Olukanni, 2020; Al-Khatib et al., 2016a, Al-Khatib et al., 2016b) and non-hazardous waste (Agunwamba et al., 2013; Eslami et al., 2017; Zeeshan et al., 2018). Hazardous wastes include infectious wastes (Azeem et al., 2018; Bandaso and Ayuningtyas, 2019; Pitaksanurat and Junggoth, 2021), chemical wastes (Dastpak et al., 2017; Elsayed et al., 2020; Stoch et al., 2018), radioactive wastes (Palmer, 2019; Petrucci and Traino, 2015; Saleh, 2016), etc. and non-infectious wastes include laboratory utensils, food, and fruits scraps, etc. (Abdo et al., 2019; Bhardwaj & Kumar, 2021; Hegde et al., 2007). It is worth mentioning that a wide range of waste disposal methods has been utilized in different countries based on the types of hospital waste and their technology access level. In developed countries, various methods such as mechanical, thermal, radiation, sewage disposal, recycling, incineration, autoclaving, electron beam technology, etc., are used for hospital waste disposal. For example, Germany, Slovenia, and Portugal are phasing incineration to protect the environment (Ali et al., 2017a).

Blockchain is a disruptive technology that has extensively been considered in waste management (Dua et al., 2020; Gopalakrishnan et al., 2021; Gupta and Bedi, 2018). Blockchain was widely known as a mechanism for the consensus process in the Bitcoin cryptocurrency but is now referred to as a technology with many applications in various fields (Tandon et al., 2020). Blockchain is a distributed ledger technology in which its members record and share transaction records (Du et al., 2021; Park and Li, 2021). Blockchain is a new, decentralized, and advanced technology that, in addition to data encryption (Kassou et al., 2021), maintains the integrity and availability of the data (Dutta et al., 2020). Moreover, the systems in which blockchain has been used provide security, integrity, and trust between parties and establish direct relationships between individuals and formal organizations (França et al., 2020). Blockchain technology has essential features such as decentralization, which refers to a database system with open access control in which data is accessible, monitored, stored, and updated in several systems (S. Ali et al., 2018; Dong et al., 2018; Monrat et al., 2019). Another feature of blockchain technology is transparency, preventing data manipulation (Abodei et al., 2019; Christodoulou et al., 2019; Lin and Liao, 2017). Immutability is one other crucial characteristic of blockchain in which records are stored forever after storage and cannot be modified or altered (Lazuashvili et al., 2019; Raikwar et al., 2018; Zheng et al., 2017). The main objective of this paper is to discuss different aspects of hospital waste management and present deep insight into the pros of blockchain applications in the hospital waste domain. By comprehensively considering the latest literature in the field, twenty-one critical factors of hospital waste systems are identified. Moreover, a framework for understanding the existing blockchain-based hospital waste systems at different levels is presented, such as applicability, critical challenges, and mitigation alternatives. The main contributions of this work are mentioned as follows:

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Providing a comprehensive classification on the state-of-the-art in HWM.

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Stating a critical discussion on solutions offered by blockchain technology to deal with the main challenges in each identified class.

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Pointing out the current limitations and presenting the emerging research issues and future research trends.

## Section snippets

## Methods

A systematic review of the literature is a validated research method as it gives researchers confidence in reaching the main concepts in the literature. The technique employed in this study is based on the way presented in (Tranfield et al., 2003). Before conducting a systematic review and identifying the keywords, an exploratory search was conducted on valid databases to obtain sufficient information regarding the study's main concepts and keywords. Fig. 1 illustrates the steps involved in the

## Bibliometric analysis and results

In this section, the output of various databases on HWM is analyzed. Hence, a quantitative analysis of selected papers was performed regarding the prevalence of documents each year, as presented in Fig. 3.

Based on Fig. 3, the prevalence of papers on HWM has increased over the years. However, the number of documents each year has not necessarily increased compared to the previous year. In this study, by integrating the output of the two databases, the relationship between the keywords was

## Blockchain-based HWM systems

This section introduces the application of blockchain and how it affects the industry. Also, the applications of blockchain technology in HWM used so far are fully described.

## Discussion and challenges

This section examines the challenges of establishing appropriate use of blockchain technology in HWM. Mechanisms designed not to manipulate information in the blockchain allow the different users to misuse the information contained in databases (Werbach, 2018). Given the importance of HWM information, this section poses a severe challenge to maintaining data in blockchain technology. Moreover, to improve the speed of access to information, the user is always provided with the information of the

## Conclusion and future work

The importance of issues related to HWM has led various studies around the world to focus on this field of study. Accordingly, one of the emerging technologies that can improve the status of HWM is blockchain technology. The primary purpose of this study was to investigate the applications of blockchain technology in HWM, examine its challenges and limitations in this domain, and present future research trends. Therefore, using a systematic review of the literature, 24 thematic subjects in the

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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I have developed WIRKS in microsoft access. how can I record the collection stance and disposal stance that it will imitate this record keeping is immuting like a blockchain tech..using Microsoft access.;we have FILE SHARIG SERVER(FSS) can I use any user as a node in a big convas. and in this manner I can use decentralize technique instead of centralised.