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Assessment of health-care waste disposal methods using a VIKOR-based fuzzy multi-criteria decision making method

Hu-Chen Liu [a,b], Jing Wu [c], Ping Li [d,e,*]

[a] School of Management, Hefei University of Technology, Hefei 230009, PR China
[b] Department of Industrial Engineering and Management, Tokyo Institute of Technology, Tokyo 152-8552, Japan
[c] Department of Public Management, Tongji University, Shanghai 200092, PR China
[d] Shanghai Pudong New Area Zhoupu Hospital, No. 135 Guanyue Road, Shanghai 201318, PR China
[e] East Hospital Affiliated to Tongji University, No. 150 Jimo Road, Shanghai 200120, PR China

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ABSTRACT

Nowadays selection of the appropriate treatment method in health-care waste (HCW) management has become a challenge task for the municipal authorities especially in developing countries. Assessment of HCW disposal alternatives can be regarded as a complicated multi-criteria decision making (MCDM) problem which requires consideration of multiple alternative solutions and conflicting tangible and intangible criteria. The objective of this paper is to present a new MCDM technique based on fuzzy set theory and VIKOR method for evaluating HCW disposal methods. Linguistic variables are used by decision makers to assess the ratings and weights for the established criteria. The ordered weighted averaging (OWA) operator is utilized to aggregate individual opinions of decision makers into a group assessment. The computational procedure of the proposed framework is illustrated through a case study in Shanghai, one of the largest cities of China. The HCW treatment alternatives considered in this study include "incineration", "steam sterilization", "microwave" and "landfill". The results obtained using the proposed approach are analyzed in a comparative way.

1. Introduction

Health-care waste (HCW) management is a major challenge task for public sectors throughout the world, particularly in developing countries (Alagöz and Kocasoy, 2008; Gai et al., 2010; Dursun et al., 2011a; Manga et al., 2011). In fact, medical and health-care wastes have sharply increased in recent decades due to the increased population, number, and size of health care facilities, as well as the use of disposable medical products (Mohee, 2005). HCW refers to waste generated from human and veterinary medical activities, and encompasses diagnosis, prevention, curative and palliative treatments, research, and laboratory activities Table 1 (Hagen et al., 2001). According to the World Health Organization (WHO), wastes from health-care institutions can be classified into nine categories as given in Table 2 (Prüss et al., 1999). Healthcare waste contains infectious pathogens, toxic chemicals, heavy metals, and may contain substances that are genotoxic or radioactive (Patwary et al., 2009; Manga et al., 2011). Poor practices and inappropriate disposal methods exercised during the handling and disposal of these wastes are creating significant health hazards and environmental pollution due to the infectious nature of the waste (Hossain et al., 2011). A survey of the WHO showed that, in 2000, injections with contaminated syringes caused 21 million hepatitis B, two million hepatitis C, and at least 260,000 HIV infections (WHO, 2005). Therefore, safe and effective treatment and disposal of medical wastes are of substantial importance because of their potential as environmental hazards and their risk to public health.

In the literature, a number of studies have been conducted in various contexts to assess HCW management practices. Normally, these studies used the prepared questionnaires, field research and personnel interviews to survey health-care facilities generating the wastes. For example, Gai et al. (2010) investigated the current status of HCW management at different levels of health care facilities after the implementation of national regulations and standards in China. Moreira and Gunther (2013) evaluated the improvements deriving from the implementation of a medical waste management plan (MWMP) in a primary health-care center located in the city of SãoPaulo, Brazil. Abd El-Salam (2010) investigated the hospital waste management practices used by eight randomly selected hospitals located in El-Beheira Governorate, Egypt and determined the total daily generation rate of their wastes. Ferreira and Teixeira (2010) analyzed the HCW management practices in hospitals of the Algarve Region, Portugal, and assessed the

* Corresponding author at: Shanghai Pudong New Area Zhoupu Hospital, No. 135 Guanyue Road, Shanghai 201318, PR China. Tel.: +86 (0)21 6813 5590; fax: +86 (0)21 6813 5715.
E-mail address: yiwuchulp@126.com (P. Li).

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Table 1
Abbreviations used in the paper.

Abbreviations	Full name
AHP	Analytic hierarchy process
HCW	Health-care waste
HIV	Human immunodeficiency virus
MCDM	Multi-criteria decision making
MWMP	Medical waste management plan
OWA	Ordered weighted averaging
VIKOR	VIsekriterijumska optimizacija i KOmpromisno Resenje
WHO	World Health Organization

risk perception of the healthcare staff and the risks to staff groups posed by waste management in these hospitals. Taghipour and Mosaferi (2009) carried out a survey about the characteristics of medical waste, i.e. quantity, generation rate, quality and composition, generated in the major city northwest of Iran in Tabriz.

In addition, to improve HCW management, some studies have indicated the importance of the use of appropriate techniques for disposal (Lee et al., 2004; Diaz et al., 2005; Rogers and Brent, 2006). In essential, selection of the suitable HCW disposal method can be viewed as a complex multi-criteria decision making (MCDM) problem and requires an extensive evaluation process of the potential disposal practices. Many potential evaluation criteria, such as economic, technical, environmental, and social criteria and their related sub-criteria, must be considered in the selection procedure of a HCW treatment alternative (Dursun et al., 2011a, b). Thus, classical MCDM techniques, such as analytic hierarchy process (AHP), have been applied to many case studies for assessment of technologies used for hospital waste management (Brent et al., 2007; Karamouz et al., 2007; Hsu et al., 2008; Karagiannidis et al., 2010). However, due to the uncertainty of information and the vagueness of human feeling and recognition, it is usually difficult and inaccurate to give exact numerical values for the selection parameters in the evaluation process. Hence, fuzzy logic or fuzzy set theory (Zadeh, 1965) has been used by many researchers to handle the vagueness involved in the HCW management problems. For instance, Dursun et al. (2011a) proposed two MCDM techniques for conducting an analysis based on multi-level hierarchical structure and fuzzy logic for identifying the most suitable HCW treatment alternative. The proposed decision approaches enable the decision makers to use linguistic terms, and thus, reduce their cognitive burden in the decision making process. Dursun et al. (2011b) presented a fuzzy multi-criteria group decision making framework based on the principles of fuzzy measure and fuzzy integral for the evaluation of HCW treatment alternatives for Istanbul, which enables to incorporate imprecise data represented as linguistic variables into the analysis.

In other way, the VIKOR (VIsekriterijumska optimizacija i KOmpromisno Resenje) method, a very useful technique for MCDM, was first developed by Opricovic (1998) to solve a discrete decision problem with noncommensurable and conflicting criteria. This method focuses on ranking and selecting from a set of alternatives, and determines compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision (Opricovic and Tzeng, 2007; Opricovic, 2011). The compromise solution is a feasible solution, which is the closest to the ideal, and a compromise means an agreement established by mutual concessions. The main advantages of the VIKOR method are that it introduces the multi-criteria ranking index based on the particular measure of "closeness" to the ideal solution (Opricovic and Tzeng, 2004), and the obtained compromise solution provides a maximum group utility for the "majority" and a minimum individual regret for the "opponent" (Opricovic and Tzeng, 2007). Due to its characteristics and capabilities, the usage of VIKOR method has been increasing in recent years (Shemshadi et al., 2011; Chauhan and Vaish, 2012; Ebrahimnejad et al., 2012; Jeya Girubha and Vinodh, 2012; Liu et al., 2012; Yücenur and Demirel, 2012; Ju and Wang, 2013; Liu et al., 2013a, in press).

In this paper, we applied the VIKOR method, which was developed for multi-criteria optimization for complex systems, to find a compromise priority ranking of treatment alternatives according to the established criteria for a disposal method selection problem in HCW management. In the group decision making process, linguistic variables are used by decision makers to assess the ratings and weights of the selection criteria. The ordered weighted averaging (OWA) operator is utilized to aggregate all individual decision makers' opinions into a group assessment. As a result, a MCDM model based on fuzzy set theory and VIKOR method is proposed to determine the most suitable treatment method in the HCW management system. The proposed methodology for group decision making can effectively deal with characteristics of this problem under fuzzy environment. Moreover, the influence of unfair arguments on the decision results can be relieved by assigning low weights to those "false" or "biased" opinions.

The rest of this paper is structured as follows. The fuzzy set theory and the OWA operator are briefly introduced in Section 2. In Section 3, we propose the VIKOR-based MCDM method for group decision making to solve the HCW disposal method selection problem with fuzzy sets. A case study is provided in Section 4 to demonstrate the computational procedure of the proposed framework and, some conclusions are made in Section 5 finally.

Table 2
Categories of health-care waste (Prüss et al., 1999).

Waste category	Description and examples
Infectious waste	Waste suspected to contain pathogens e.g. laboratory cultures; waste from isolation wards; tissues (swabs), materials, or equipment that have been in contact with infected patients; excreta
Pathological waste	Human tissues or fluids e.g. body parts; blood and other body fluids; fetuses
Sharps	Sharp waste e.g. needles; infusion sets; scalpels; knives; blades; broken glass
Pharmaceutical waste	Waste containing pharmaceuticals e.g. pharmaceuticals that are expired or no longer needed; items contaminated by or containing pharmaceuticals (bottles, boxes)
Genotoxic waste	Waste containing substances with genotoxic properties e.g. waste containing cytostatic drugs (often used in cancer therapy); genotoxic chemicals
Chemical waste	Waste containing chemical substances e.g. laboratory reagents; film developer; disinfectants that are expired or no longer needed; solvents
Wastes with high content of heavy metals	Batteries; broken thermometers; blood-pressure gauges; etc.
Pressurized containers	Gas cylinders; gas cartridges; aerosol cans
Radioactive waste	Waste containing radioactive substances e.g. unused liquids from radiotherapy or laboratory research; contaminated glassware, packages, or absorbent paper; urine and excreta from patients treated or tested with unsealed radionuclides; sealed sources