Journal of Hazardous Materials 284 (2015) 92–102

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

GHG emission control and solid waste management for megacities with inexact inputs: A case study in Beijing, China

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HIGHLIGHTS

- This study advances an integrated MSW management model under inexact input information.
- The model can minimize net system cost and mitigate GHG emissions.
- The model is particularly developed for the city of Beijing, China.
- It reduces system cost by [45, 61]% and mitigates GHG emissions by [141, 179]%.
- It could provide implications to megacities regarding GHG emissions control.

ARTICLE INFO

Article history:
Received 10 August 2014
Received in revised form 9 October 2014
Accepted 28 October 2014
Available online 13 November 2014

Keywords:
Greenhouse gas emission
Mitigation
Solid waste management
Uncertainty
Beijing

ABSTRACT

This study advances an integrated MSW management model under inexact input information for the city of Beijing, China. The model is capable of simultaneously generating MSW management policies, performing GHG emission control, and addressing system uncertainty. Results suggest that: (1) a management strategy with minimal system cost can be obtained even when suspension of certain facilities becomes unavoidable through specific increments of the remaining ones; (2) expansion of facilities depends only on actual needs, rather than enabling the full usage of existing facilities, although it may prove to be a costly proposition; (3) adjustment of waste-stream diversion ratio directly leads to a change in GHG emissions from different disposal facilities. Results are also obtained from the comparison of the model with a conventional one without GHG emissions consideration. It is indicated that (1) the model would reduce the net system cost by [45, 61]% (i.e., [3173, 3520] million dollars) and mitigate GHG emissions by [141, 179]% (i.e., [76, 81] million tons); (2) increased waste would be diverted to integrated waste management facilities to prevent overmuch CH_4 emission from the landfills.

1. Introduction

Municipal solid waste (MSW) management is not only essential to human health and natural environment, but also an important yardstick to assess the urbanization level in developing countries [1,2]. Due to the continually and rapidly increasing generated-amount of MSW, as well as the decreasing capacity of waste treatment facilities, MSW management has already been attracted the attention as an acute issue both domestically and internationally. MSW, whose annual growth is approximately 2.6% since the 2000s, has reached 6.7169 million tons in 2013 [3]. Current studies indicate that MSW, during its treatment and disposal processes, is the major contributor to greenhouse gas (GHG) emissions, leading to a significant impact on environment change [4–7]. As landfilling is the principal measure of MSW disposal in Beijing, a large number of GHGs are emitted in the city, and the gases emanating from them are let out into the atmosphere. This contributes significantly to regional climate changes and environmental pollution. In response to this concern, the development of integrated MSW management models has become imperative for the local government, which sound scientific support and practical reference with appropriate management strategies to control GHG emissions.

Recently, there have been a series of studies on developing various models to support MSW management [8–13]. For example, Hsieh and Ho [14] presented a linear programming approach to optimize a typical waste disposal system. Kuhner and Harrington [15] suggested the use of mixed integer programming (MIP) mod-

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http://dx.doi.org/10.1016/j.jhazmat.2014.10.051
0304-3894/

els for dynamic investment policies of regional MSW management. Masqood and Huang [16] developed a two-stage interval-stochastic programming (TISP) model for planning of MSW management systems under uncertainty. He et al. [17] developed a flexible interval mixed-integer bi-infinite programming (FIMIBIP) method that allows for the parameters in the objective, and constraints of the programming problem to serve as functional intervals. Together with these attempts in model development, a number of practical applications have also been reported [18–21]. Guo et al. [22] studied an MSW decision-support system for long-term planning of waste management with interval-parameter fuzzy-stochastic semi-infinite mixed-integer linear programming.

China has since 2010 overtaken the United States as the largest GHG emitter, accounting for approximately 32% of the total GHG emissions in 2013. In accordance with the work plan for controlling greenhouse gas emissions for the Twelfth Five-Year Plan period, CO_2 equivalent per unit of GDP should be cut among each of the cities in China to 21% in 2015 below the 2010 level (i.e., 22.3%), in terms of the low-carbon growth plan. GHG emissions during MSW disposal processes have, of late, been causing widespread concern [23,24]. Case studies, especially with regard to GHG emissions, of MSW management systems have been implemented for most developed countries and some developing countries, with the dual purpose of optimization of the management process and reduction in GHG emissions [25–27]. For example, Sandulescu [28] studied the contribution of effective waste management strategies for GHG emission control for the city of Bucharest, Romania, and found that about 5.5% of the total GHG emissions can be mitigated. Mohareb et al. [29] used an integrated waste management model to explore GHG emissions from the waste sector in Ottawa, Canada; results showed that waste incineration, further source separation of recyclables, and anaerobic digestion of organic wastes had the greatest benefits for reducing GHG emissions. Based on the Tianjin case, Zhao et al. [24] used life cycle assessment to evaluate six scenarios for GHG emissions mitigation in MSW management, and results showed integrated MSW management scenario had the highest GHG mitigation potential scenario under different improvement options.

From the previous research, it is indicated that the carbon dioxide equivalents released from waste management activities in Beijing have been growing from 2010, and will peak in 2026, with 54,367 m^3/h. In fact, a megacity like Beijing, choosing an inappropriate waste management strategy may worsen these problems by increasing the risk levels of negative health and environmental degradation. Another associated problem is the enhanced difficulty in relevant parameters estimation because of lack of available sufficient statistical information, while identifying the right MSW management strategies [30]. However, there has been few previous studies focusing on developing integrated MSW management strategies with GHG-emission control in megacities. Accordingly, it is desired that the suitable strategies adopted be capable of concurrently tackling integrated MSW, mitigating GHG emissions and addressing inexact input information, in order to attain sustainable environmental management.

Therefore, this study aims to propose an integrated MSW management model to support MSW management and GHG-emission control, particularly for the city of Beijing, China. This model will be useful in (1) simultaneously dealing with the complex trade-off of system cost and mitigation of GHG emissions under a set of social, environmental, infrastructural, and technical restrictions, (2) identifying integrated MSW management strategies which involve optimal waste flow allocation, besides facilitating expansion plans, (3) providing useful guidelines to megacities like Beijing with regard to integrated MSW management.

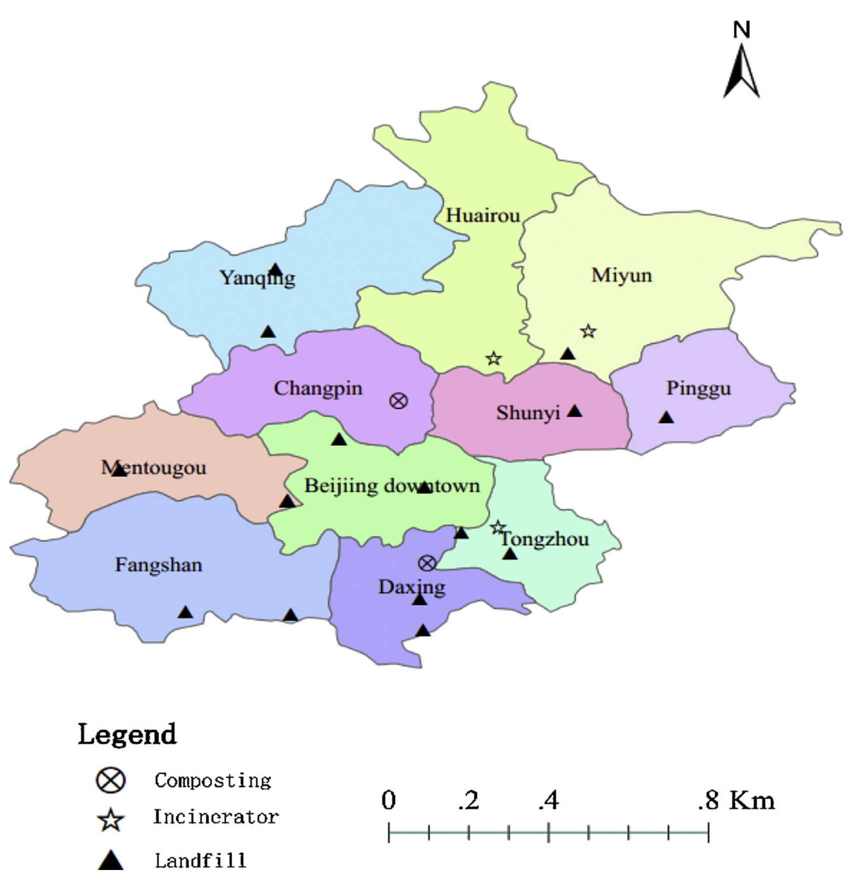

Fig. 1. The study area and distribution of disposal facilities in Beijing