



The 4 "R" Conference

Reduce, Reuse, Recycle, Rethink!

www.swananorthernlights.org

MAY 5 – 8 2008

REGINA, SASKATCHEWAN

Ramada Hotel & Convention Centre

1818 Victoria Avenue, Regina, SK • www.saskramada.com

Development of a community-based participatory network for integrated solid waste management

Cai, Yanpeng, Guohe Huang, Qian Tan and Gongchen Li

Department of Civil and Environmental Engineering, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada *Corresponding author: Department of Civil and Environmental Engineering, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada.

Email: caiyangpeng@iseis.org; Tel: (306) 585-5631

Major theme of the research is to develop a participatory network for integrated solid waste management under uncertainty and complexity through a broad participation of stakeholders. The network can integrate relevant factors, processes, objectives and their interactions into a general modeling framework through comprehensive data collection, participatory modeling formulation and interactive policy analysis. Methods of questionnaire survey, systems analysis, stochastic process forecasting and inexact optimization will be jointly employed to allow systematic and comprehensive consideration of a number of social, economic, environmental and technical issues that are related to solid waste management at a community scale. It is anticipated that the proposed research can be directly useful for accomplishing integrated solid-waste management in many communities. The proposed network can be effective for easing the environmental burdens that exacerbate local people, strengthening the capacity of the stakeholders to access environmental services. The research outcomes include (a) results of the nature of environmental burdens and their impacts, (b) a participatory network for the collaboration of poor urban communities, NGOs, service providers and multiple-scale governments, (c) techniques for the promotion of community involvement and public participation in formulating policies related to integrated solid waste management, and (d) optimal decision alternatives for the collection, storage, transportation and disposal of solid waste.

Keywords: solid waste management, management, community scale, participatory network





The 4 "R" Conference

Reduce, Reuse, Recycle, Rethink!

www.swananorthernlights.org

MAY 5 – 8 2008

REGINA, SASKATCHEWAN

Ramada Hotel & Convention Centre

1818 Victoria Avenue, Regina, SK • www.saskramada.com

1. Introduction

Management of solid waste in cities are not only associated with various environmental implications to atmosphere, soil and water-body, but also intertwined with socio-economic conditions of the urban communities, posing a variety of complexities for the relevant process of decision making in the solid waste management system. Furthermore, extensive uncertainties exist in many processes and factors in the solid waste management due to geographical, political, economic and legislative conditions, leading to raised complexities in making relevant decisions. All of these uncertainties and complexities pose great challenges for decision makers in many cities across the world. In order to address these issues, a holistic perspective, which comprehensively considers the processes and factors involved in the activities of waste collection, transportation and treatment, as well as their interactions and implications, is desired for supporting effective solid waste management. This leads to the development of a participatory community-based network which is based on comprehensive investigation, inexact optimization modeling and interactive policy analysis. The proposed network can thus be employed for integrated solid waste management and sustainable urban development in the municipal context.

2. Methodology

2.1. Literature review

Due to urbanization and industrialization across the world, solid waste management has now become a global issue (Bulle, 1999; Cai et al., 2007). Many researchers proposed a number of technological options to find viable alternatives for appropriate management and disposal of solid waste. Their studies significantly established the fact that solid waste management is far from just a technical issue (dalla Torre, 1999). Instead, the management of solid waste has various socio-political, economic and cultural dimensions that need solutions through imaginative policies, administrative reorientation, institutional and organizational arrangements and an informed population within a general network.

Conventionally, a few researchers argued that private or public management of the MSW systems is the most efficient irrespective of the nature of the resource to be managed or the socioeconomic conditions of people associated with the resource (Kant and Berry, 2001). Also, in order to reflect in-depth interactions between urban poverty and solid waste management, more attention has been given to urban poor. Given access to important resources like land and even a minimal support from external groups and institutions, low-income communities can improve and maintain a decent and livable environment. Lee (1998) suggested that the provision of support by external NGO's has shown great potential as catalysts in assisting low-income communities in terms of empowerment and environmental issues. Douglas et al. (1997) argued that facilitation and implementation of such community-based efforts as empowering strategies for the poor and improving their access to important environmental resources, particularly land, infrastructure and services, is necessary for environmental management. Klundert and Lardinois (1999) suggested that a top down approach to community development might not be effective or sustainable. They state that intervention agencies, even with the best intentions, cannot impose 'foreign' concepts and programs, and expect positive





The 4 "R" Conference

Reduce, Reuse, Recycle, Rethink!

www.swananorthernlights.org

MAY 5 – 8 2008

REGINA, SASKATCHEWAN

Ramada Hotel & Convention Centre

1818 Victoria Avenue, Regina, SK • www.saskramada.com

and sustainable results. [Mockler \(1998\)](#) studied community-based solid waste management systems in Indonesia. Her study suggested that a 'felt need' is a necessary prerequisite for successful implementation of a community-based solid waste management system. More specifically, [Anschutz \(1996\)](#) suggested that community-based waste projects might fail because of low participation from households. If solid waste management was not a 'felt need', this will have consequences for their participation in the service and their willingness to pay. [Dhungel, \(1997\)](#) conducted research in Balaju, a community near Kathmandu, Nepal. [Salequzzaman et al. \(2000\)](#) conducted a study in Khulna city, Bangladesh and found that formal and informal education and training by external institutions had influenced community members' willingness to pay. [Selvam \(1996\)](#) investigated participation in a communally organized collection and recycling program and found that 70% of the people were against separation of waste at home because it was inconvenient. [Yayasan \(1998\)](#), working in Padang, Indonesia, described management of community-based solid waste services as often being a voluntary activity. [Anschutz \(1996\)](#) studied waste collectors and explained that their salary was generally low because they merely derived their income from waste collection fees and often from the sale of recyclables.

Although there were a number of studies on the management of solid waste under a community scale at many locations especially in developing countries, most of them were limited to qualitative analysis of the developed systems. There was a lack of studies on participatory network development based on scientific tools and public participation. Also, these studies could hardly integrate [MSW](#) management and its environmental and socio-economic implications into a general framework. They hardly tackle the process for the development of an integrated [MSW](#) management system in a quantitative way. Few of these studies viewed [MSW](#) management and urban poverty reduction from a holistic perspective, which might lock the generated policies into a narrow scope and neglect adverse effects. This would highly narrow the depth of the research results and lower their potential applicability. Also, they did not analyze the development of a network connecting communities and private/public sectors which can be a successful approach in strengthening urban environmental management. This would significantly affect the broadness of their obtained solutions. In a summary, these studies can hardly deal with (a) the integration of various environmental impacts into a general framework for the management of solid waste management, (b) comprehensive studies for the interactions with the urban-poor and other communities/sectors in the municipal context like the City of Regina, (c) interactions of solid waste management with poverty alleviation and women's participation, (d) participatory network integrating both horizontal and vertical interactions of financial and environmental capabilities, and (e) sustainable programs within communities for long-term information-transferring.

Therefore, in order to fill in these gaps and contribute to the advancement of knowledge in the areas of solid waste management and urban-poverty reduction. The project will be proposed to effectively deal with these problems and develop a participatory network for integrated MSW management. An innovative theoretical methodology will be proposed with interactive participation of a diverse range





The 4 "R" Conference

Reduce, Reuse, Recycle, Rethink!

www.swananorthernlights.org

MAY 5 – 8 2008

REGINA, SASKATCHEWAN

Ramada Hotel & Convention Centre

1818 Victoria Avenue, Regina, SK • www.saskramada.com

of stakeholders in the study city. This methodology will base on a series of technologies and approaches which are linked together for achieving the overall goal of this project. A comprehensive perspective for solid waste management will be adopted through the integration of solid waste generation, collection, storage, transportation, disposal and treatment, and the integration of various economic and environmental implications of solid waste management (air pollution, noise, soil and groundwater contamination, and health-related concerns), as well as the integration of a large number of multi-disciplinary participants, multiple sectors and communities. The methodology follows a procedure of data collection, investigation and characterization, literature review, modeling formulation, network development and policy analysis.

2.2. Solid waste management network at a community scale

The existing waste management practices can hardly let all key stakeholders (e.g. various levels of governments, research centers, industries, end-users, communities and associations) being involved in an integrated solid waste management system. This results in lacks of incentives for research centers to develop innovative technologies and enterprises to improve service quality due to the current institutional framework. As for the proposed participatory network, multi-layer interactions exist in system components, process activities and factors in the study cities. ***Firstly***, interactions exist in the municipal solid waste management system and other community-based subsystems. Policies and strategies at different jurisdictions may be interrelated to each other. Any changes in one subsystem will lead to a series of consequences to and responses from the others, and thus affect the entire management system. ***Secondly***, interactions exist in solid-waste-related activities (e.g., waste generation, storage, transportation, and treatment), with varying implications of social and economic/environmental effects (e.g., social equity, gender issue, public participation and urban poverty alleviation). ***Thirdly***, competitions and interactions may exist between relevant technologies and policies for solid waste treatment under different communities. Any alteration in a technology will lead to corresponding responses from the entire network. ***Fourthly***, interactions exist among the related processes and technologies. A network contains a number of processes and technologies for transferring various sources of solid waste to energy or ashes, which compete with each other in terms of resource availability, capacity development and environment limit. ***Fifthly***, multidimensional interactions may exist when multiple types of uncertain information existing in many uncertain components and subsystems. ***Sixthly***, many social, political and legislative conditions under different communities would have complex and uncertain interactions with the network.

2.3. Development of an optimization-model-based participatory network (OMPN) – A

participatory optimization-model based network for supporting solid waste management and poverty reduction will be developed in the study cities under complexities of multidimensionality, nonlinearity and uncertainty. It will focus on a wide range of issues related to solid waste management and poverty reduction. The main activities of this task will focus on the development of





The 4 "R" Conference

Reduce, Reuse, Recycle, Rethink!

www.swananorthernlights.org

MAY 5 – 8 2008

REGINA, SASKATCHEWAN

Ramada Hotel & Convention Centre

1818 Victoria Avenue, Regina, SK • www.saskramada.com

an interactive optimization model for supporting the management of solid waste and poverty reduction. An integrated optimization model for network-based solid waste management (NSWM) systems under uncertainty will be developed. A set of multidimensional inexact optimization methods will be developed for tackling various complexities (e.g. nonlinearity, multiobjective, multi-interaction and dynamics) and multiple uncertainties, and for facilitating robust solid waste systems management within a participatory network. An inexact multiobjective two-stage program (IMTSP) will be developed for tackling uncertainties and facilitating risk management. A general IMTSP model can be formulated as, Min:

$$\{ f_k^{\pm}[X^{\pm}, E(Y^{\pm})] \mid g_r^{\pm}(X^{\pm}) \leq B_r^{\pm}, r=1,2,\dots,m_1; g_t^{\pm}(X^{\pm}, Y^{\pm}) \geq w_h^{\pm}, t=1,2,\dots,m_2; h=1,2,\dots,v; x_j^{\pm} \geq 0, x_j^{\pm} \in X^{\pm}; j=1,2,\dots,n_1; y_{jh}^{\pm} \geq 0, y_{jh}^{\pm} \in Y^{\pm}; j=1,2,\dots,n_2 \}.$$

IMTSP can not only reflect compromises among multiple conflicting objectives but also analyze various scenarios that are associated with different economic penalties (Huang et al., 2003; Maqsood et al., 2005).

2.4. Policy analysis – Post modeling analysis (PMA) can help acquire information excluded from mathematical models, so that applicability of modeling results to practical situations can be enhanced (Huang, 1998). A knowledge-based system will be built to facilitate PMA, where public participation will be conducted for validating inputs/outputs and generating desired decision support. The system can support in-depth examination of implicit and qualitative information such as social and political factors that are deemed crucial by decision makers. It can also perform trade-off analyses among multiple economic and environmental objectives. Rating- and ranking-based fuzzy multi-criteria decision analysis methods will be integrated into the developed multidimensional inexact optimization frameworks, and help generate more realistic decision alternatives under uncertainty.

Also, governments, institutes, communities, research centers, industries and end-users will have their interests related to solid waste management. Working with these groups must be effectively coordinated. Therefore, the network will be advanced for strengthening the capacity of the study cities in developing and implementing the co-operation programs both for solid waste management and poverty reduction. It will allow all stakeholders to work together to help improve the integrated MSW management through actions of communication, cooperation and coordination. The network will be implemented for facilitating capacity building of the stakeholders and for enhancing their interactions within the MSW management framework. Research outputs will be useful for tackling conflicts among various objectives and generating desired strategies within a municipal context. The potential policy improvements could refer to not only formulation and/or supplementation of the related policies and regulations, but also the generation of more complementary, integrated and effective strategies for solid waste system management. Recommendations can be provided based on the results of impact assessment, decision analysis, and community involvement studies, as well as multi-criteria analysis of the related environmental and socio-economic objectives. Approaches for implementing decision alternatives under various policy scenarios could be identified through extensive applicability and feasibility analyses. Relevant suggestions and recommendations will be generated and provided.





The 4 "R" Conference

Reduce, Reuse, Recycle, Rethink!

www.swananorthernlights.org

MAY 5 – 8 2008

REGINA, SASKATCHEWAN

Ramada Hotel & Convention Centre

1818 Victoria Avenue, Regina, SK • www.saskramada.com

Through these methods, capacity of local stakeholder in understanding the nature of environmental burdens from solid waste can be highly improved. Impacts from solid waste on urban poverty can also be reflected. Potential solutions will be generated through the proposed models and the interactive network. It is useful for testing interventions and assessing policies in low-income urban neighborhoods that seek to ease environmental burdens and enhance the use of natural resources for food, water, and income security. Thus, the proposed project will contribute to the integrated planning of solid waste, development, and implementation of sustainable and equitable urban environmental and natural resources practices and policies. These are also emphasized in IDRC and its objectives.

3. Application to the study city

3.1. City of Regina, Canada

The City of Regina is the capital of the Province of Saskatchewan, and is located in the heart of western Canada. The population of the city is about 190,400, where the households generate residential wastes of about 70,000 tonne (City of Regina, 2000). Solid waste management in the City covers many areas, ranging from garbage collection to environmental protection. It involves the provision of specific and personal services to most of the residents (through waste collection and recovery) as well as indirect services to the whole community (through waste disposal and recovery). Recent population projections assumed a growth rate of 0.7% per year in the City (Sae-Lim, 1999). The results of a waste characterization study for the City indicated that the residential sector of Regina generated waste at a rate of approximately 1.17 kg/capita/day (Barlshen, 1996; Chi and Huang, 1998). The municipal solid wastes generated typically include paper, yard waste, food waste, plastics, metals, glass, wood, and other items. Therefore, for the long-term planning exercise, a general waste generation rate of 1.00-1.17 kg/capita/day will be used for the residential sector of the City.

3.2. Chengdu City

Chengdu City, which is located in southwest China, is the capital of Sichuan province and a sub-provincial city. It is the fifth most populous city in China with an area of 11,939 km² (Chengdu government, 2007). Chengdu City is also one of the most important transportation and communication hubs in China. Along with a large population and rapid urbanization, tremendous amounts of solid waste are generated in the City. The total amount of waste is 2,400 tonnes per day and 880,000 tonnes per year, with an annual increasing ratio of 5% (Chengdu government, 2007). Waste-generation increment and its interactions with population growth, economic development, urban-poverty expansion pose great challenges for sustainable development in the City, requiring great efforts for managing solid waste from a participatory and integrated perspective.

4. Conclusion

Development of the optimization-model-based participatory network (OMPN) for comprehensively studying network characterization, system optimization, solid waste management and community





The 4 "R" Conference

Reduce, Reuse, Recycle, Rethink!

www.swananorthernlights.org

MAY 5 – 8 2008

REGINA, SASKATCHEWAN

Ramada Hotel & Convention Centre

1818 Victoria Avenue, Regina, SK • www.saskramada.com

involvement represents a unique contribution to methodologies for sciences of waste management and social works. The OMPN allows systematic consideration of factors that are related to decisions of solid waste management strategies, and are directly useful for generating both solid waste management plans and urban development alternatives. The concept of OMPN can also be used for developing information systems for other environmental and waste management problems in a variety of industries. The integrated approach regarding network characterization, optimization model based network, integration of community involvement, and policy analysis as developed in this project represents a unique contribution to methodologies for supporting solid waste management under multiple uncertainties. The proposed methodology will allow more systematic and comprehensive considerations of a number of critical social, economic, environmental and technical factors that are related to waste management and urban development at the community scale as well as their interrelationship and related policy implications. If successfully funded by TD, this proposed research will spill over other regions of Canada and other developing countries, and can be directly useful for accomplishing more effective waste management. The developed methodologies will provide supports for addressing the most challenging problems associated with solid waste management and urban development at a community scale within a city. To facilitate technical innovation, the associated research will focus on the fundamental understanding of the participatory network at urban communities. Innovative methodologies and technologies will be developed through systems characterization and investigation, optimization, uncertainty analysis, and policy-analysis studies. Moreover, the proposed research will contribute much to the development of protocols for conducting comprehensive and integrated solid waste management.

References

- Anschutz, J. (1996). Community-Based Solid Waste Management and Water Supply Projects: Problems and Solutions Compared: A survey of the literature. UWEP Nieuwehaven. UWEP Working Document.
- Barlisen, D.K., 1996. Waste Characterization Study, University of Regina, Regional Environmental System Engineering.
- Bulle, S. (1999). Issues and Results of Community Participation in Urban Environment: Comparative Analysis of Nine Projects on Waste Management. UWEP Nieuwehaven. UWEP Working Document.
- Cai, Y.P., Xu, L.Y., and Yang, Z.F. (2002) Public participation in the study of TVIEs's environmental performance. Journal of Beijing Normal University (Natural Science), 38(1): 138-143.
- Cai, Y.P., Yang, Z.F., and Xu, L.Y. (2003) Valuing Health Impairment Resulting From Air Pollution In Tianjin's Township-Village Industrial Enterprises. Journal of safety and environment, 3(1): 33-36.
- Cai, Y.P., Huang, G.H., Nie, X.H., Li, Y.P., and Tan, Q. (2007a) Municipal solid waste management under uncertainty: a mixed interval parameter fuzzy-stochastic robust programming approach. Environmental Engineering Sciences, 24 (3): 338-352.
- Cai, Y.P., Huang, G.H., Lu, H.W., and Nie, X.H. (2007b). I-VFRP: An Interval-Valued Fuzzy Robust Programming Approach for Petroleum Waste Management Planning under Uncertainty. Engineering Optimization, accepted.
- Cheng, S., Chan, C.W., Huang, G.H., 2002. Using multi-criteria decision analysis for supporting decisions of solid waste management. Journal of Environmental Science and Health A 37 (6), 975 - 990.
- Chi, G.F., Huang, G.H., 1998. Long-term planning of integrated solid waste management system under uncertainty. Report summated to the City of Regina, University of Regina, Saskatchewan, Canada.





The 4 "R" Conference

Reduce, Reuse, Recycle, Rethink!

www.swananorthernlights.org

MAY 5 – 8 2008

REGINA, SASKATCHEWAN
Ramada Hotel & Convention Centre
1818 Victoria Avenue, Regina, SK • www.saskramada.com

- City of Regina, 2000. Solid Waste Management Plan.
- City of Regina, 1989. Waste Management Study Phase II. M.M. Dillon Limited, Regina, SK.
- dalla Torre, C. (1999). Municipal Solid Waste Management in Developing Countries: Problems and Issues: Need for Future Research.No. 26. SANDEC publication. Switzerland.
- Dhungel, K. (1997). Women in Environment Implement a Squatter Settlement Improvement Project, In: Waafas O.A., Phileo, W., (Eds.) 1992. Partners in Life: Proceedings of the Global Assembly of Women and the Environment, November 4-8, 1991, Miami. (WorldWIDE Network in Collaboration with the United Nations Environment Programme, Washington, D.C., 1992).
- Douglas, M., Lee, Y.S., and Lowry, K. (1997). Urban Poverty and Environmental Management in Asia. Asian Journal of Environmental Management 2(1), 7-14.
- Huang GH, Baetz BW, Patry, GG. (1995). Grey integer programming: an application to waste management planning under uncertainty. European Journal of Operational Research; 83: 594-620.
- Huang, G. H. and Chang, N. B. (2003). The Perspectives of Environmental Informatics and Systems Analysis. Journal of Environmental Informatics. 1(1), 1-7.
- Maqsood I, Huang G.H. and Yeomans, J.S. (2005). An interval-parameter fuzzy two-stage stochastic program for water resources management under uncertainty. European Journal of Operational Research. 167(1), 208-225.
- Kant, S., Berry, A. (2001). A Theoretical Model of Optimal Forest Resource Regimes. Journal of Theoretical and Institutional Economics 157, 331-335.
- Klundert, A., van de., Lardinois, I. (1999). Community and Private (Formal and Informal) Sector Involvement in Municipal Solid Waste Management in Developing Countries: background paper for UMP. Gouda.
- Lee, Y.S., (1998). Community Based Urban Environmental Management: Local NGO's as Catalysts. Regional Development Dialogue 15(2), 158-176.
- Liu, L., Huang, G. H., Liu, Y. and Fuller, G. A. (2003). A fuzzy-stochastic robust programming model for regional air quality management under uncertainty. Engineering Optimization. 35(2), 177-199.
- Luo, B., Maqsood, I., Yin, Y. Y., Huang, G. H. and Cohen, S. J. (2003). Adaption to Climate Change through Water Trading under Uncertainty - An Inexact Two-Stage Nonlinear Programming Approach. Journal of Environmental Informatics. 2(2), 58-68.
- Mockler, M. (1998). Community-based solid waste management in Indonesia. Background Paper for World Bank Jakarta.)
- Sae-Lim, N., 1999. Long-term planning of a solid waste management system under uncertainty—an inexact optimization approach. M.A.Sc. Thesis, University of Regina, Regina, SK, Canada.
- Salequzzaman, M. Awal, S., Alam, M. (2000). Willingness to Pay for Community-Based Solid Waste Management and its Sustainability in Bangladesh. Working Paper. Proceedings of the Habitus 2000 Conference in Perty, Aust.
- Selvam, P. (1996). A Review of Indian Experiences in Composting of Municipal Solid Wastes and a Case Study on Private Sector on Private Sector Participation. Conference of Recycling Waste for Agriculture: The Rural-Urban Connection. September 23, 24. Washington, D.C.
- Yayasan, D.D. (1998). Study on Community Based Primary Collection of Solid Waste in Indonesia. Field Report In: Pfammatter, R.and Schertenleib, R. 1996. Non-Governmental Refuse Collection Systems. 22nd WEDC Conference, New Delhi.

