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Waste Management Pinch Analysis (WAMPA) for carbon emission reduction

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Abstract

Improper waste management happened in most of the developing country where inadequate disposal of waste in landfill is commonly practiced Apart from disposal, MSW can turn into valuable product through recycling, energy recovery, and biological recovery action as suggested in the hierarchy of waste management. This study presents a novel method known as waste management pinch analysis (WAMPA) to examine the implication of recycling and landfill reduction target on the carbon emission. WAMPA aims to identity waste management strategies (waste to energy (WTE), recycling, reduce, reuse) based on specified landfill reduction target and carbon emission target. WAMPA is capable to examine the capacity of each strategy groups through graphical representation, and is also capable to provide meaning and illustration to the effect of changing of target toward the needs of each strategy.

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Keywords: Carbon emission, , pinch analysis, solid waste management (SWM), waste-to-recycle (WTR), waste-to-energy (WTE), reduction and reuse.

1. Introduction

The generation of municipal solid waste (MSW) has increased in parallel to the rapid population growth, and with changing consumption patterns, economic development and rapid urbanization. Improper waste management happened in most of the developing country where inadequate disposal of waste in landfill is commonly practiced. It caused long-term impacts to the environmental, such as pollution of air, soil, surface and ground water, in addition, reduce valuable space of land for landfill. One

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of the major consequences of landfill is the generation of methane (CH_4) gas from the decomposition of MSW, where CH_4 is contributed to about 21% of global greenhouse gasses (GHG). The negative consequences of landfill are the driving forces for the government and municipalities to identify better solutions for waste management planning. Apart from disposal, MSW can turn into valuable product through recycling, energy recovery, and biological recovery action as suggested in the hierarchy of waste management [1]. Regional solid waste management (SWM) strategy are often performed via optimisation tool which is often optimized in a "black-box" optimization mathematical model. However, to enhance understanding and comprehension of the strategy, a visual technique would be vital. Among the optimization techniques present, pinch analysis which has been largely applied through many application is significantly important.

Pinch analysis poses the advantage of simplified complicated mathematical modeling while presented visual results is useful for communication of decision makers and stakeholders [2]. Pinch analysis was first invented to address energy consumption problems in chemical engineering process [3], it is now has been extended beyond energy applications to other areas, including mass exchange networks [4, 5], water pinch [6-13], hydrogen pinch [14-16], and carbon emission pinch [17-20]. Conventional pinch analyses are used to define the target (demand chain) of a process system based on the information of stream quantities and quality (supply chain) for a micro-scale industries planning. With contrast to the conventional pinch approaches, Tan and Foo [17] developed carbon emission pinch analysis (CEPA) to address the carbon emission constraints issue arise from energy sectors for macro scale regional planning. In CEPA, the carbon reduction target from the energy sector was set based on national or regional development plan, then emissions reduction action is decided to achieve the set target. CEPA extends the conventional pinch analysis technique from industrial sites to broader macro-scale applications into electricity generation sector to optimise the generation mix based on demand/emissions targeting [17, 18].

This study presents a new application of pinch analysis in SWM planning. The proposed Waste Management Pinch Analysis (WAMPA) is an analog to the existing CEPA. WAMPA aims to identity waste management strategies (waste to energy (WTE), recycling, reduce, reuse) based on specified landfill reduction target and carbon emission target. In this article, the general methodology of WAMPA will be presented through a demonstration of a SWM case. It is then followed by the result and discussion, and finally conclusion.

2. Waste Management Pinch Analysis (WAMPA)

WAMPA is designed base on CEPA which requires the user to set a target and construct a supply curve base on existing implemented strategies to meet a newly set target. In the case of WAMPA, aside for carbon emission target, it also include landfill reduction target. The supply curve, which represent waste treatment, processing, and disposal capacity is grouped into three categories in WAMPA. The three categories are describe below:

- Carbon emission from landfill – emission of methane gas (translated into carbon emission equivalent) due to natural decomposition
- Carbon emission from WTE – emission of carbon dioxide during conversion of waste to energy
- No emission strategies – strategies such as reduce, reuse and recycling (3R) that does not produce greenhouse gas

The representation of each curve is shown in Figure 1. As for the methodology of WAMPA, the step by step methodology is shown below:

Step 1: Construction the existing waste processing capacity curve (WPCC)
Step 2: Set a target of carbon emission reduction and reduction of waste to landfill
Step 3: Shift a part (portion of waste still sent for landfilling) of the WPCC which represents landfill carbon emission to the new carbon emission target (the line is arrange to be below the target, working from the target to the origin)
Step 4: Shift the portion of existing WTE curve to the new curve (beginning from the end of the landfill curve)
Step 5: Extend the WTE curve so that it touches the x-axis, the extended portion of the curve represent additional WTE strategies to be implemented.
Step 6: Maintain the “No emission strategies” curve
Step 7: Extend the “No emission strategies” curve to the WTE curve, the extended portion of the curve represent additional “No emission strategies” to be implemented.

For clarity on the described method, an illustration of each category of curve and the general procedure of the technique is presented in Fig.1. Table 1 on the other hand shows the details of the information required for the analysis. It is also noted that the technique only comprehend one waste source at a time. As such, two illustration, paper waste and food waste will be shown, other waste which naturally does not produce carbon dioxide in landfills are not demonstrated. These waste source include, glass, metal, and plastic (non-biodegradable). Fig. 2 shows the procedure for food waste targeting.

Table 1 Data for WAMPA analysis

	Year 2005	Year 2020
Food waste (tonne)	230,000	300,000
Paper waste (tonne)	40,000	65,000
[a]Landfill emission of food waste (tonne CO2/tonne waste)	0.5868	
[a]Landfill emission of paper waste (tonne CO2/tonne waste)	0.3686	
[a]General emission of WTE (tonne CO2/tonne waste)	0.28	
Landfill reduction of food waste (%)	85	
Landfill reduction of paper waste (%)	70	
Carbon emission reduction (%)	20	

a. reference [22]

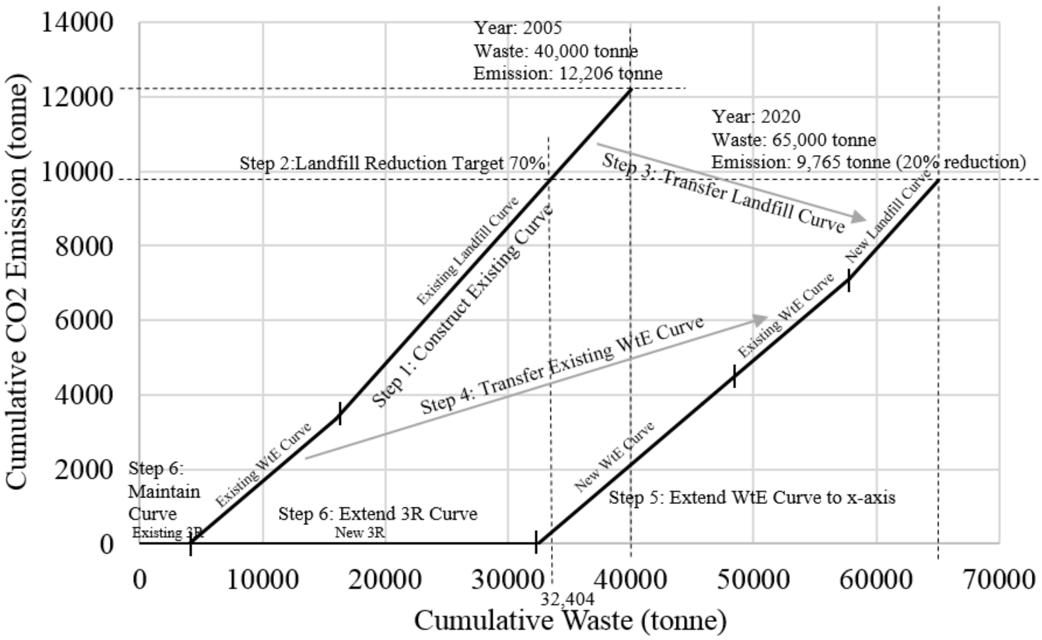

Fig. 1 WAMPA for paper waste management

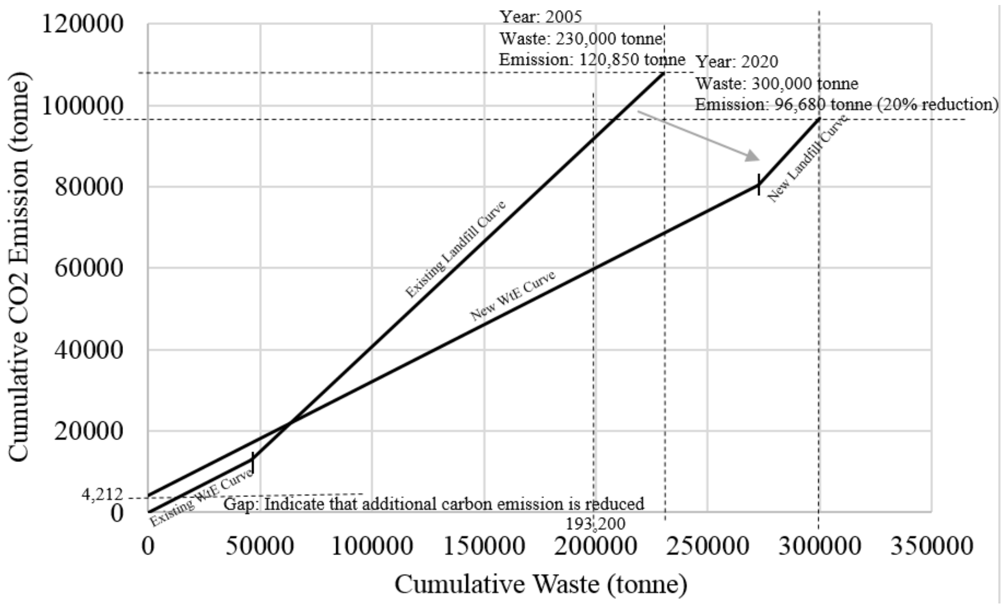

Fig. 2 WAMPA for food waste management

In addition, WAMPA is also capable to illustrate the effect of landfill reduction and carbon emission target to the needs of advanced waste management strategies. By reducing or increasing the amount of waste to landfill and carbon emission, different strategy for 3R and WTE may be implied. An example of the effects is demonstrated in Section 3.

3. Results and Discussion

Based on the case study, it is suggested to meet up to 20% carbon emission reduction and paper waste to landfill by 70%, additional 13,396 tonne in capacity of WTE technology and additional 28,404 tonne in capacity of 3R practices have to be implemented for paper waste. The total paper disposal strategy required by 2020 includes 7,200 tonne to be landfilled, 25,396 tonne to be converted to energy, and 32,404 tonne to be mitigated through 3R practices.

As for food waste, to meet 20% reduction of carbon emission and 85% of food waste to landfill, 226,400 tonne in capacity of WTE technology have to be implemented in order to achieve the set target. The total WTE technology for food waste in 2020 is recommended to be able to process up to 272,400 tonne of food waste. Also in Figure 2, it is illustrated that the WTE curve intersects the y-axis at 4,212 tonne CO_2 (new WTE curve is located above the original WTE curve). This indicates an additional of 4,212 of CO_2 can be further reduce. On the other hand, if the new WTE curve falls below the original WTE curve, it indicates that the carbon emission cannot be achieved. However this can be done by further reducing the allocation of waste to landfill to reduce carbon emission from landfill which is higher than the carbon emission from WTE.

To further illustrate the effect of landfill emission, WTE emission, and 3R practices, the effect of is shown in Fig. 3 for paper waste management.

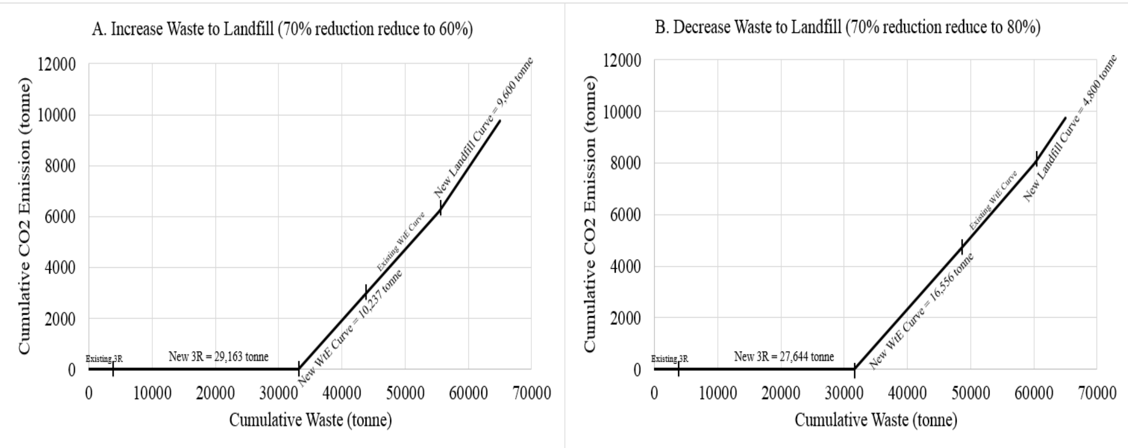

Fig. 3. Effect of (A) increasing and (B) decreasing allocation for landfilling toward other waste management strategies

Base on Fig. 3, by increasing paper waste to landfill (reduction from 70% of previous landfill allocation to 60%), the amount of waste allocation for new WTE decreases 10,237 tonne, and new 3R increases to 29,163 tonne in order to maintain the targeted carbon emission of 9,765 tonne. The reason for decreasing allocation for WTE is due to increase emission from the landfill. On the contrary, by reducing paper waste to landfill, the amount of waste allocation for new WTE increases to 16,556 tonne and new 3R decreases to 27,644 tonne.

4. Conclusion

Base on the overall outcome of the study, while WAMPA is able to identify the capacity of each group of strategy, it does not select the type of technology and its corresponding capacity to be implemented. Selection of technologies which usually is subjected to other factors of consideration could be done with other optimization technique such as mathematical programming. Nevertheless, WAMPA could simplified the search by revealing the targets for total required capacity of each group of strategy for implementation.

In summary, WAMPA is capable to identify the capacity of each strategy groups through graphical representation, and is also capable to provide meaning and illustration to the effect of changing of target toward the needs of each strategy.

Acknowledgements

These and the Reference headings are in bold but have no numbers. Text below continues as normal.

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Biography

Associate Prof. Dr. Haslenda Hashim a research fellow for PROSPECT of UTM. She specialises in process planning/scheduling, modeling and optimization for low carbon society (LCS), renewable electricity generation, waste to wealth, and fugitive emissions. Dr Haslenda and her team won the prize of Highly Commended under the IChemE Sustainable Technology Award category in the Chemical Engineers (IChemE) Global Award 2014