Commingled vs Separated Waste Collection in Tulkarem (West Bank - Palestinian Territories): Preliminary Result Of an Environmental, Economic And Social Analysis

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Abstract—In the Middle East and in Palestine municipal waste generation increased very fast in the last years and the aim of this work is to support local authorities to choose the best municipal waste collection system.

The paper examines the results obtained from an environmental, economic and social comparison between two different real scenarios for waste collection in Tulkarem (West Bank): the first scenario foresees the commingled collection managed by public authority, while the second one is based on a cardboard separated collection managed by private informal collection activity.

The comparison takes into account environmental, economic and social aspects. The carbon foot print tool has been used to address some environmental key aspects and the global acceptance of the two considered scenarios. As concerns the economic point of view, conventional economic criteria (direct and indirect costs), i.e. fuel and labor costs, recycling gain and disposal costs have been considered to evaluate the economic aspects. Concerning the social aspects, worker safety conditions and salary have been evaluated.

The results revealed that the informal separated waste collection option is preferable from the environmental and economical point of view, while the formal commingled option is better from the social point of view.

The integrated analysis performed in Tulkarem case study was important to support the local Municipality decision making process, towards a more sustainable waste management scheme. More generally, the comparison methodology that has been defined and used for the scenarios of the considered case can establish a more general useful approach, in order to help the definition of the best solution for waste collection planning.

Index Terms—Carbon Foot Print, Decision Making, Palestinian Territories, Waste Collection Planning

I. INTRODUCTION

Municipal Solid Waste Management (MSWM), which comes into being to tackle waste problems, is a necessary part of human life and effective management of waste has been identified as essential for human sustainability [1]. Waste problems consist of environment pollution, resource depletion and public health problems, such as the spread of diseases, which relate to environmental, economic and social issues of sustainability [2] that must be addressed.

This paper analyzes, with an holistic approach, 2 different scenarios of waste collection in a medium size Palestinian town in the West Bank, considering environmental, economic and

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social sustainability, with the aim of supporting local authority in the decision making process to define the best municipal waste collection system.

The waste generation in Palestine and the generation rate per capita were estimated in 2012 equal to 1,387 million tons and 0.94 kg/day respectively. It is estimated that waste generation rate per year increases by 4%; where 3% increase is due to natural population growth, and 1% is due to increase in generation rate per capita. The waste collection rate has increased from about 64% in 1994 to 92% in 2011. Solid waste collection is conducted mainly by municipalities or Joint Service Councils (an association of several municipalities to provide one or more service for all member municipalities) [3].

The study is based on data collected in Tulkarm, a medium size Palestinian town located in the Tulkarm Governorate, with a population about 51,000 and per capita production of 394 kg/year. The research was performed in the framework of the cooperation project "Green Tulkarem" run by Italian NGO CESVI. The promotion of separated collection and recycling of municipal waste is one of the aim of the project.

The case study examined is composed of 2 different scenarios: the first one foresees the commingled collection managed by public authority, while the second one is based on a cardboard separated collection managed by private informal collection activity.

In the West Bank in 2010, recycling was about 6,400 tons/year which is equivalent to less than 1% of the waste. Furthermore, it can be estimated that most of the recovered material is cardboard [3] . In Tulkarem, cardboard collection produced by commercial activities is operated by an informal group of people that evolved in the creation of a small company (Oufi Company), which manage collection, transport, compaction and sale of this kind of recyclable material. The quantity of waste collected by Oufi Company represent the 6 % of the total production of municipal waste in Tulkarem. The informal cardboard collection is organized in parallel to the formal commingled collection managed by the municipality and the aim of this paper is quantifies the environmental, economic and social impacts of this 2 different collection systems.

II. MATERIALS AND METHODS

A. Data Collection Methods

During 2014 and 2015, the authors analyzed the collection and recycling system in the Region through the local main stakeholder meeting, such as municipalities, Joint Service Councils (JSC) and private companies operating in waste

management sector in West Bank. The analysis of informal collection system in Tulkarem, was performed through meetings, focus group and semi structured interviews with key informants and selected players in the collection and recycling chain.

The subjects involved in these activities were:
- Tulkarem municipality
- Tulkarem Joint Service Council (JSC), an association of local authorities that is created to provide for community services, including waste management
- Oufi Company, a small company who runs cardboard collection in Tulkarem and it is in transition from informal to formal sector
- CESVI, an Italian NGO who coordinates the project "Green Tulkarem"

The field observation of the collection system activities was crucial to understand the Tulkarem recycling system.

The cardboard collection system was analyzed recording collection routes by the software Motion X GPS V23.0 Build5030R32 (www.motionx.com/home/technology).

The data collected served as inputs to the environmental, economic and social analysis and contributed to an understanding of the diversity of arrangements within the waste collection.

B. Description Of Scenarios

- *Commingled collection (CC):* the CC scenario reflects the current principal state of municipal waste management in Tulkarem. The town's commingled waste are collected by the municipality operators using compactor trucks (average size 20 mc) and transported in a transfer station in Tulkarem suburbs (distance from town center to transfer station 6 km). In the transfer station commingled waste is hand over in containers and then are transported to sanitary landfill (distance from transfer station to sanitary landfill 40 km) when the containers are full.
- *Cardboard separated collection (SC):* the SC scenario reflects a secondary municipal waste management in Tulkarem. The cardboard waste produced by commercial activities (like supermarkets, printing shops, groceries) are separated and collected by the informal sector using a pickup truck (size 6 mc) and transported in a storage area (distance from town center to transfer station 2 km). In this area the material is pressed using a vertical electric baler (supposed baler power 7,5 kW) and the bales are transferred in container and when the containers are full they are sold to a recycling company and transported to Israel (estimated distance from storage area to recycling center 50 km).

C. Data Elaboration Methods

Environmental Aspect

The protocol for the quantification of greenhouse gas emissions from waste management activities is developed by the EPE (Entreprises pour l'Environnement) [4] was used to quantify the GHG implications of the 2 different scenarios.

The protocol considers 3 kinds of emissions:
- Direct Emissions. Direct GHG emissions occur from process or equipments owned or controlled by the entity
- Indirect Emissions. Indirect GHG emissions are emissions

that are consequences of the activities of the entity but that physically occur at sites or during operations owned or controlled by another organization than the reporting entity
- Avoided emissions. Certain waste treatment activities generate energy (electricity & heat) as a by-product and/or contribute to the re-use of materials or fuels. Energy and material recovery can contribute to avoid GHG emissions compared to a baseline scenario.

The impact of waste management decisions on GHG emissions has to be evaluated for two main reasons. Firstly, climate change poses an urgent threat to the functioning of our biome, and carbon emitted has become an essential metric for decision making. Secondly, GHGs released under different waste management scenarios can function as an indicator of overall environmental impact, given that lower emissions are correlated with lower energy consumption and resource extraction [5].

Economic Aspect

The economic aspect was evaluated considering a costs indicator (CI) which represents the specific cost per ton of managed commingled solid waste. It is defined as the sum of the following specific costs:
- Costs of collection, costs of the commingled collection
- Cost of transport I, costs of the transport from the town to the transfer station
- Costs of storage, operational costs at the transfer station
- Cost of transport II, costs of the transport from the transfer station to sanitary landfill
- Costs of final disposal, cost of disposal into sanitary landfill.

Social Aspect

The social impact was evaluated analyzing these parameters for each scenario:
- Formal employment agreement
- Use of personal protective equipment (PPE) during collection activities
- Compensation per hour
- Working hours per day

These data were elaborated using the Social Footprint Method (SFM), who is a context-based approach to measurement and reporting the social sustainability performance of an organization. The Social Footprint is a narrow application of context-based sustainability, which in its broader form covers sustainability performance in all of its dimensions, not just the social one [6].

The elaboration consists of:
- conversion and standardization of each parameter in a social indicator
- calculation of the global social indicator for each scenario
- comparison of social indicator considering the CC scenario as the usual context
- the SC scenario social footprint was calculated using the formula below

$$Social\ fooprint\ (SF) = \frac{social\ impact\ of\ SC\ scenario}{social\ impact\ of\ CC\ scenario}$$

$$\begin{cases} SF \geq 1 \text{ is sustainable} \\ SF < 1 \text{ is unsustainable} \end{cases}$$

III. RESULTS

The estimated quantity of cardboard collected by the informal activity (Oufi Company) is 1,296 ton/years and it represents the 6 % of the total waste production in Tulkarem. The quantity was obtained monitoring the collection activities of the informal pickers, recording with the GPS system the collection path and weighing the quantities collected for each collection trip.

This research work compares the 2 different scenarios calculating environmental, economic and social impacts of this quantity of waste in the 2 different situation:

- Scenario CC, the waste are collected in commingled collection
- Scenario SC, the waste are collected in cardboard separated collection

Environmental Impact

First step of the environmental evaluation was the estimation of fuel consumption in 2 different scenarios, considering for each one 2 different stages who composed them (Table I). In both scenarios first stage is collection and transportation to an intermediate plant (transfer station in CC scenario and storage area in SC scenario). Second stage is transport to sanitary landfill in CC scenario and to recycling facility in SC scenario.

The total fuel consumed is similar for both scenarios,

Table I. Fuel consumption

	Scenario CC		Scenario SC	
Stage	**Fuel consumption (liter)**		**Stage**	**Fuel consumption (liter)**
(1) Collection and transport to the transfer station	1,283		(1) Collection and transport to the storage and treatment area	2,592
(2) Transport to the sanitary landfill	2,333		(2) Transport to the recycling facility in Israel	1,080
TOTAL	**3,616**			**3,672**

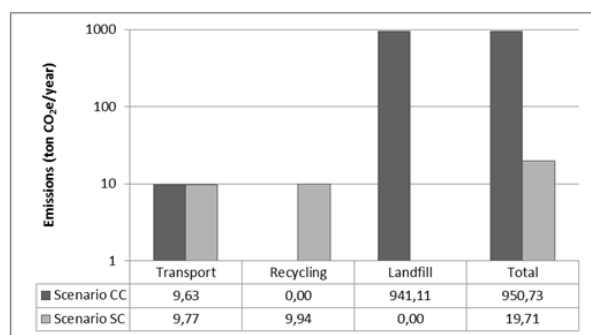|	Transport	Recycling	Landfill	Total
■ Scenario CC	9,63	0,00	941,11	950,73
▥ Scenario SC	9,77	9,94	0,00	19,71

Chart 1 GHG total production

although in SC scenario the consumption is higher in the first stage due to the inefficiency of the collection conducted by a small and old truck without a compaction system. But in the second stage the SP scenario is more efficient and the fuel

consumption is lower because before the transportation the material is pressed.

These fuel consumptions were used as entry data to calculate the GHG production using the "Protocol for the quantification of greenhouse gas emissions from waste management activities" and data obtained are showed in Chart 1 (log scale). For calculating GHG production landfill emission in CC scenario and recycling activities emission in SC scenario were considered.

CC scenario was the option with the highest greenhouse gas emissions due to the high production of CO_2e for disposal in landfill.

Economic Impact

The current informal separate collection system does not incur in any direct economic costs to the municipal government, therefore the authors have considered only the costs of commingled collection assume separated collection cost for the municipality zero.

In Table II unitary costs of collection, transport and disposal for CC scenario are showed.

Considering the estimated quantity of waste collected through the SC scenario (1,296 ton/years) it is possible calculate that the Municipality saves each year approximately 43,500 USD .

Table II Unitary costs of collection, transport and disposal for CC scenario

Stage	Unitary cost (USD/year)
Collection and transport I (town - transfer station)	$ 16.53
Storage (transfer station)	$ 3.56
Transport II (transfer station – sanitary landfill)	$ 5.85
Costs of final disposal (sanitary landfill)	$ 7.63
Total cost	**$ 33.57**

Table III. Social parameters and indicators analyzed

Social parameter	CC scenario		SC scenario	
	Result	Indicator	Result	Indicator
Formal employment agreement	Yes	1	No	0
Use of personal protective equipment (PPE) during collection activities	Yes	1	No	0
Compensation per hour	--- (*)	1	--- (*)	0,5
Working hours per day	8	1	10	0,8
	TOTAL	**4**	**TOTAL**	**1,3**

(*) Data not available

Social impact

In Table III are showed the social parameters and indicators which were evaluated and calculated:

- Formal employment agreement
- Use of personal protective equipment (PPE) during collection activities
- Compensation per hour
- Working hours per day

The social footprint of the SC scenario was calculated using this formula:

$$Social\ fooprint\ (SF) = \frac{measure\ of\ the\ social\ impact\ SC\ scenario}{measure\ of\ the\ social\ impact\ CC\ scenario}$$

And it results 0.325 and it means that SC scenario is not sustainable considering social aspects.

IV. DISCUSSION AND CONCLUSION

Understanding how informal actors work in the waste sector is essential to the implementation of integrated waste management systems in the Global South [7].

In Tulkarem the informal collector Oufi Company increases the quantity of waste materials that are recycled by diverting waste materials from the landfill and rerouting them to be reprocessed. This system emits fewer GHGs than does the municipal's formalized recycling system, improving the environmental impact of the waste management.

In the economic point of view this study has shown that municipality reduce collection and management costs of 43,500 USD per year by the separated collection, principally because cardboard is not disposed in the sanitary landfill.

Considering the social aspects the informal separated collection it is not sustainable, because informal collectors are exposed to occupational hazards, and do not use protective equipment while working.

In conclusion, it is evident that this study has revealed that the informal separated waste collection option is preferable from the environmental and economical point of view, while the formal commingled option is better from the social point of view.

On the basis of the findings presented in this paper, it could be useful that the Municipality supports the informal collection system considering important environmental and economical results produced by the improvement of the working condition of the Oufi company operators.

ACKNOWLEDGMENT

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