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GHG Emission from Trucks During Collection of Solid Wastes: Çorlu Case Study

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ABSTRACT

Kerbside collection is most common method in Turkey for solid waste collection. Çorlu has increasing population rate due to growing industrial activities and investments. Information used in the study such as; average waste collection amount in a month, truck properties (volume, engine power) and travelled distance during waste collection were obtained from Çorlu Municipality. Total fuel consumption of trucks during collection of 1-ton waste for 1-km is between 2.12-5.47 L diesel / ton in Çorlu. Greenhouse gas emissions for different scenarios were calculated in this study. First, GHG emission estimation done for same volume trucks using different fuel types, second estimation done for trucks with the same engine power using different fuel types. GHG emissions for Çorlu were calculated using emission coefficients for; diesel, gasoline, heavy oil, light oil, natural gas fuels from literature sources. Maximum emission is found as 35 kg CO_2-eq /ton, in case of using heavy oil in the 3.5 m^3 vehicle and minimum emission is occurred 5,08 kg CO_2-eq while using natural gas in 13+1,5 m^3 truck. Contrary to expectations, kg CO_2-eq / ton value (which is show the GHG emission rate) is decrease while the engine power (horsepower) increases. It has been determined that there are significant differences in GHG emissions when the truck and/or fuel type are changed, even without changing factors such as route, waste collection frequency and number of stops (number of containers).

Keywords: Emission, fuel type, greenhouse gas, waste collection.

INTRODUCTION

Economic, social and environmental impacts should be accounted while creating waste management system. Number of studies have been conducted to understand short and long-term environmental impacts of GHG emissions to the atmospheres. The largest share of anthropogenic GHG emissions belongs to the energy sector with 68%, and 90% of these emissions created as a CO_2. According to researchers CO_2 emissions in the world for the transport sector remains same as 20% between 1990-2014. However, this constant value is calculated as an overall so there are some exceptions such as Ireland. Transport sector accounts for 36% of total emissions in Ireland and it's more than the 20% world average value given above (GerDevlin, 2010). The International Energy Agency emission report highlights given in Table 1 shows that the transport sector has 4.5 % of all CO_2 emissions due to fuel consumption.

Table 1. CO_2 emissions by sector in 2014 (IEA,2016)

Million tonnes of CO_2	**Total CO_2 emissions from fuel combustion**	**Electricity and heat production**	**Other energy and Industrial own use**	**Manufacturing industries and construction**	**Transport**	**Road**	**Other sectors**	**Residental**
World	32.381	13.625	1.683	6.230	7.547	5.659	3.295	1.858
Turkey	307.1	132.1	11.2	44.9	60.9	55.2	57.9	28.1

Differently from IEA study according to the TurkStat's report, total greenhouse gas emissions in Turkey in 2015 were calculated as 475.1 million tons (Mt) CO_2 equivalent. The largest share of CO_2 emissions in the year 2015 was energy-related emissions with 71.6% followed by industrial operations and product use by 12.8%, agricultural activities by 12.1% and waste by 3.5% (TÜİK,2015) While calculating CO_2 emissions in these kind of searching reports, emission factor is also take into account. The emission factor is used mainly for include effect of ash or residue which are not completely burned after combustion. Equation (1) is used for calculation of emissions.

$$CO_2 \text{ Emission from fuel combustion} = \text{fuel combustion} \times \text{emission factor} \quad (1)$$

During the use of fuel (diesel) in vehicles some gases are formed such as CO, HC, NOx, SO_2 and also PM. However, they are generally calculated in terms of CO_2 eq.(Larsen et al. 2009). In order to prevent air pollution, countries have set emission limits and the European Union has set the standards for the vehicles which are possible source of emissions. According to 2009/30/EC Directive "The combustion of road transport fuel is responsible for around 20 % of community greenhouse gas emissions" (Diesel-net, 2017). For example last version of Euro standartd was published in 2013 and limitations are shown in Table 2.

Table 2. Lists emission standards applicable to diesel (Diesel-net, 2017)

Stage	**Date**	**CO (g/kWh)**	**HC (g/kWh)**	**NO_X (g/kWh)**	**PM (g/kWh)**
Euro VI	2013	1.5	0.13	0.4	0.01

Modeling programs and various scenarios are used in life cycle analysis for emission calculations in solid waste management. Generally, scenarios are focused on disposal types such as compost, incineration and landfill. In these kind of studies, waste collection and transportation processes are neglected or considered as same for each scenario. For instance transport and waste management processes GHG emission ratios are shown in Figure 1 as 2.8% . However waste management ratio only include disposal processes like landfilling, incineration. GHG emissions during waste collection are shown under the head of transport (19.5%) . So, aim of this study is to find out GHG emissions due to waste collection process seperately from other tranport activities in Çorlu.

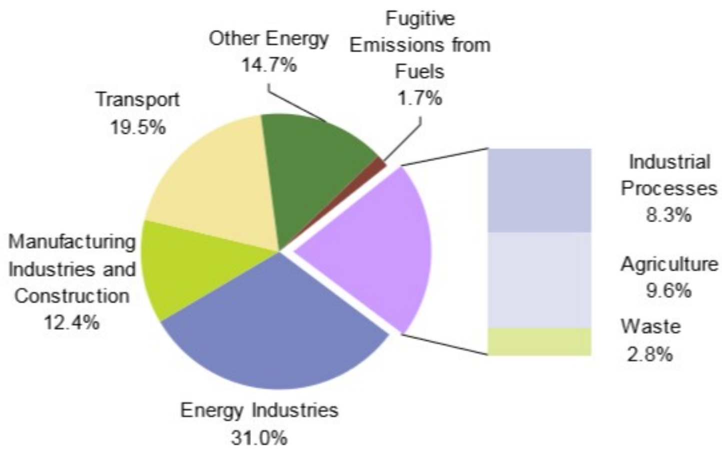

Figure 1. CO_2 emissions by sectors (Bolla and Pendolovska, 2011)

WASTE COLLECTION TYPES

The collection of waste is the responsibility of the district municipalities in Turkey (Belediye Kanunu, 2005). Transportation processes are under the command of Metropolitan Municipalities. If the city isn’t in the metropolitan scale, again district mucipalities are responsible for both collection and transport processes. Since each municipality has a different administrative structure, waste collection doesn’t have general practice in Turkey.

Waste Collection Defination

There are different definitions in the literature for the collection and transportation processes. According to İzzet Öztürk's Solid Waste Management and EU Harmonized Practices book definition; The first stage of collection is house to the can, second stage is can to truck, third stage truck from house to house, the fourth stage is truck routing and final stage is truck to recycle or disposal area (Figure 2) (Öztürk, 2010).

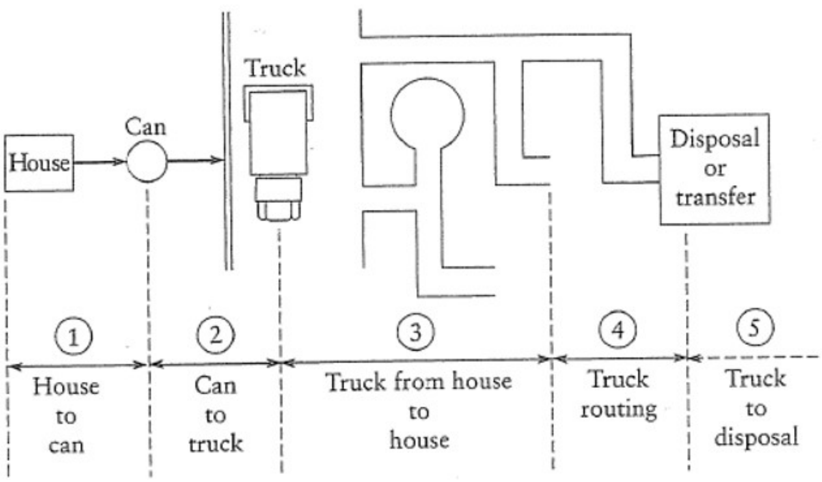

Figure 2. Collection process steps (Öztürk, 2010).

Mixed Collection

Mixed collection is a widely used system, recycble wastes and biodegradable waste are collected together (as a mixture). Mixed wastes are usually collected with packer trucks.

Seperate Collection of Recyclable Wastes

Two basic methods exist for collecting recyclable wastes, first bringing method (bringing by the customer/waste producer, drop-off) and second collecting from source (receiving from the customer/waste producer).

During this study, mixed waste collection is assumed and the collection process is completed when the collection route is over. So transportion process starts when the waste came to end of the collection route and/or transfer station.

Waste Collection Ways

Solid wastes are collected in six different category according to the collection ways.

- Side of the street, (curb, kerbside)
- With the mechanical equipment from the street side, (curb-mechanic)
- On the way to the roads, (alley)
- Return from the private property to the collection container (setout-setback or only Setout)
- Being from the back garden of a private property. (backyard carrying)
- Collection of wastes with pipe (pneumatic)

Backyard is mostly used in United states while pneumatic system generally used in Spain. In order to measure the environmental impact of different collection ways, kerbside and pneumatic waste collection system were compared during study contacted in Spain (Usón et al. 2013). Pneumatic waste collection system is more efficient at high waste quantities. As the amount of waste increases, more trucks will be needed in the kerbside system and this case will cause more emissions (Usón et al. 2013). Furthermore, in pneumatic systems after the initial energy required for the operation of the system (for vacuum) is given, the energy requirement is less during operation. When the waste rate increases, the efficiency of the system increase to (Usón et al. 2013). In another study done in Spain pneumatic, multi-container and door to door systems were compared (Iriarteab et al. 2009). Life cycle analysis was performed for different parameters, ultimately for urban short-distance scenarios when the total energy requirements of the systems are considered, the largest energy requirement is needed for pneumatic system (Iriarteab et al. 2009). Two studies done in the same country have shown that there is no single general rule on the environmental impact of the collection systems. The results are relative to the region conditions.

MATERIAL AND METHOD

Various researchs have done for the use of different fuel types and their effects on environment. For example; research done in Madrid compares total energy consumption and greenhouse gas emissions, during use of diesel, biodiesel and natural gas fuels (López et al, 2009). Research results shows emission for biodiesel is 2.30 kg CO_2 eq / km, for diesel 2.25

kg CO_2 eq / km and 1.90 kg CO_2 eq / km for natural gas (López et al, 2009). In this study, total greenhouse gas emissions were obtained from research conducted in Denmark (López et al, 2009). GHG emissions for Corlu were calculated using emission coefficients for; diesel, gasoline, heavy oil, light oil, natural gas fuels (Fruergaard et al. 2009).

Table 3. Fuel provision + combustion emissions (Fruergaard et al. 2009)

Fuel Type	Minimum emission factor (kg CO_2-eq/L)	Maximum emission factor (kg CO_2-eq/L)
Diesel	3,1	3,2
Gasolin	3	3
Heavy Oil	3,3	3,5
Light Oil	3,1	3,2
Natural Gas	2,4	2,5

* study uses four different life cycle analysis databases, so there is no single coefficient for emissions of fuels, and there are maximum and minimum values.

When previous literature reviews are searched, it is seen that fuel consumption is in the range of 1.4-10.1 L diesel / ton (Larsen et al. 2009). In another study, this range found as 1.6-10.1 L diesel / ton (Eisted et al. 2009). One of the reasons of gap between maximum and minumum values is the different route of each truck. The length of each route is different and also number of containers in each route are variable. As the number of containers increases, the amount of fuel consumed per ton varies, because it will cause trucks to increase in stopping, waiting (for emtying the container) and re-starting when the waste is collected during route. In addition, distance to the unloading point (transfer station, MRF, landfill etc.), size of the collection area, truck properties and driver are important factors affecting fuel consumption per ton waste (Larsen et al. 2009).

Kerbside collection is most common method in Turkey for solid waste collection (Öztürk, 2010). Çorlu has increasing population rate due to growing industrial activities and investments. Information used in the study such as; average waste collection amount in a month, truck properties (volume, engine power) and travelled distance during waste collection were obtained from Çorlu Municipality. Unsanitary waste discharge is still continuing in Çorlu. After the integrated solid waste management plant will constructed and necessary optimization studies are carried out, wastes will be directly sent to landfill. Table 4 shows volume of truck, average trips in a month, average fuel consumption in a month, average road travel in a month and fuel consumption in a unit (ton) waste collected data. Higher fuel consumption for unit waste collected belongs to 5m^3 collection trucks.

Table 4. Collection trucks and fuel comsumption in Çorlu

engine power	**volume of truck**	**avg. trips in a month**	**avg. fuel consumption in a month**	**avg. waste collection in a month**	**avg. road travel in a month**	**travelled road in a trip**	**fuel consumption in a trip**	**fuel consumption in a unit (ton) waste collected**
(HP)	(m^3)	trip	(Lt)	(ton)	(km)	(km)	(Lt)	(Lt/ton)
252		50,0	930	314,7	2.170	43,4	18,6	2,96
252		45,0	930	356,5	2.015	44,8	20,7	2,61
182		31,0	950	186,0	3.265	105,3	30,6	5,11
252		60,0	1.200	310,0	2.480	41,3	20,0	3,87
252		55,0	950	448,5	2.325	42,3	17,3	2,12
252	13	31,0	950	341,0	2.945	95,0	30,6	2,79
182		40,0	775	325,5	2.325	58,1	19,4	2,38
243		31,0	1.240	403,0	2.325	75,0	40,0	3,08
243		31,0	1.250	372,0	2.400	77,4	40,3	3,36
243		31,0	1.200	341,0	2.300	74,2	38,7	3,52
Avg.		**40,5**	**1.038**	**339,8**	**2.455**	**65,7**	**27,6**	**3,18**
177		50,0	775	285,0	2.900	58,0	15,5	2,72
177	8	40,0	775	290,0	2.500	62,5	19,4	2,67
Avg.		**45,0**	**775**	**287,5**	**2.700**	**60,3**	**17,4**	**2,70**
177		40,0	775	294,5	1.900	47,5	19,4	2,63
177	7	45,0	775	296,5	2.480	55,1	17,2	2,61
Avg.		**42,5**	**775**	**295,5**	**2.190**	**51,3**	**18,3**	**2,62**
182		40,0	930	170,5	1.860	46,5	23,3	5,45
182	5	40,0	930	170,0	1.860	46,5	23,3	5,47
Avg.		**40,0**	**930**	**170,3**	**1.860**	**46,5**	**23,3**	**5,46**
150	3,5	31,0	465	46,5	2.460	79,4	15,0	10,0

Fuel consumption of trucks during collection of 1-ton waste for 1-km is between 2.11-5.47 L diesel/ton in Çorlu. Fuel consumption ranges are reported as 1.4-10.1 L diesel/ton and 1.6-10.1 L diesel/ton in previous studies so in the light of these literature informations, values obtained from Çorlu Municipality are suitable for emission calculations (López et al. 2009; Eisted et al. 2009). According to calculation results as it seen in the Figure 3, amount of fuel consumption is decreased with increase in truck volumes in Çorlu.

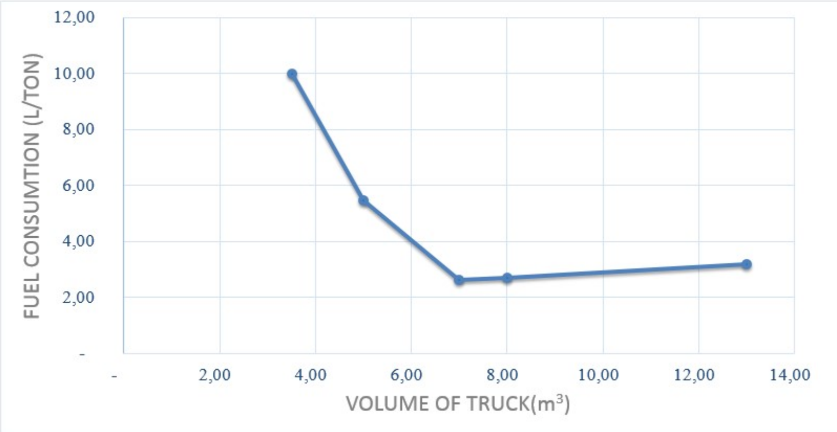

Figure 3. Change in Fuel Consumption vs Truck Volume

Same comparison is done for changing engine power of the trucks. 252 hp trucks have least fuel consumption for unit waste collected. (Figure 4)

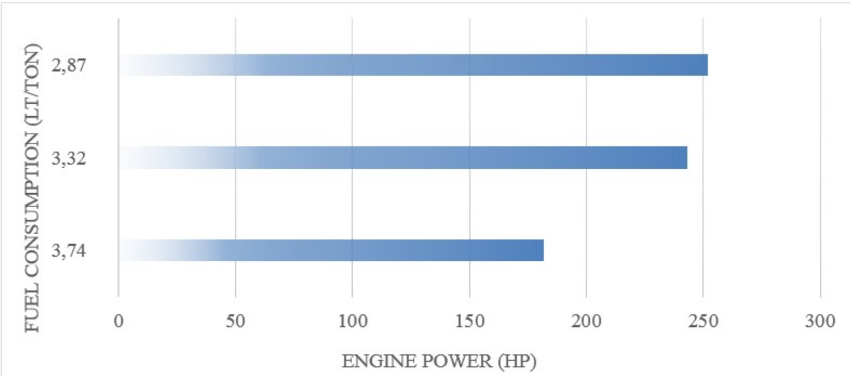

Figure 4. Change in Fuel Consumption vs Fuel Comsumption

In this study, greenhouse gas emissions for different scenarios were calculated. Firstly, GHG emission estimation done for same volume trucks using different fuel types, second estimation done for trucks with the same engine power using different fuel . Fuel consumption in a unit waste collected (L/ton) and emission factor (kg CO_2-eq/L) are multiplied for the calculation of GHG emissions (kg CO_2-eq/ton) during collection of wastes in Çorlu.

RESULTS AND DISCUSSION

When GHG emissions for the different engine powers and variable fuels are calculated, heavy oil used in 182 hp engine causes maximum GHG emission while natural gas used in 252 hp engine causes minimum GHG (kg CO_2-eq/ton) emission. All of the results are compatible with previous studies releated to waste collection emissions (Larsen et al. 2009). Figure 5 and Figure 6 shows maximum and minimum emissions ranges.

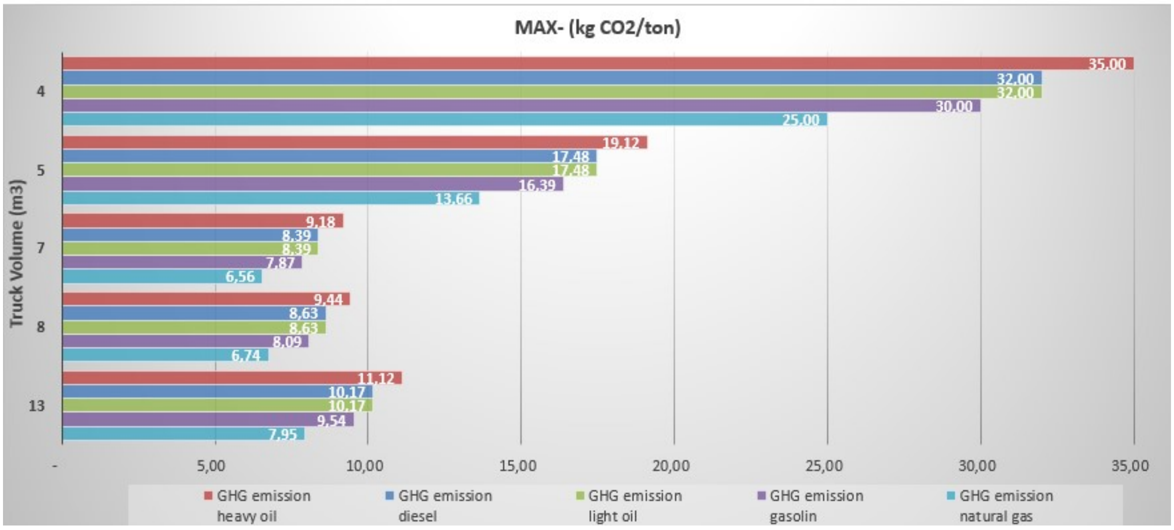

Figure 5. Minimum GHG emissions (kg CO_2-eq/ton) while using same truck volumes

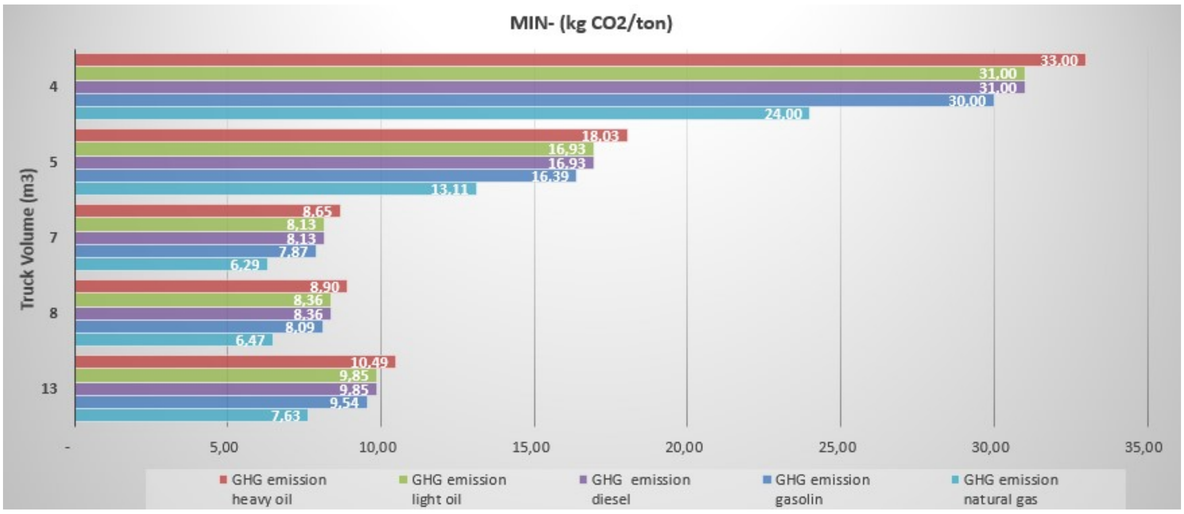

Figure 6. Maximum GHG emissions (kg CO_2-eq/ton) while using same truck volumes

GHG emissions during waste colletion comparison also done for different engine power trucks and results are like in Figure 7. Higher engine capacity trucks (252 hp) have lower CO_2 eq. emission for unit waste collected. This result direclty releated to amount of fuel consumption for unit waste collected which is shown in above Figure 4. Maximum CO_2 eq. emission is occurred durin usage of 182 hp engine power truck and heavy oil.

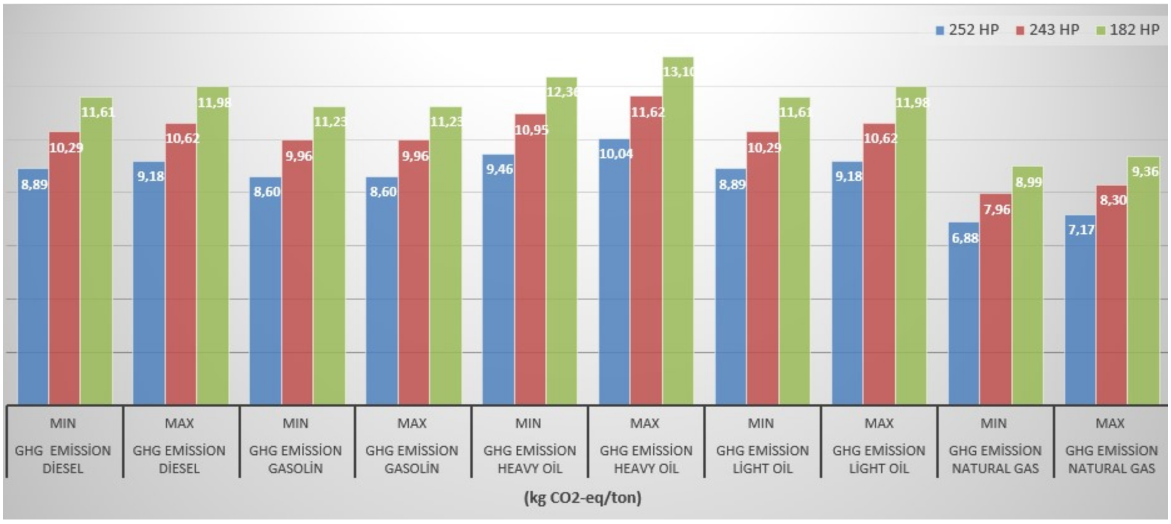

Figure 7. Maximum and minimum GHG emissions (kg CO_2-eq/ton) while using different engine power trucks

DISCUSSION

Maximum emission is found as 35 kg CO_2-eq / ton, in case of using heavy oil in the 3.5 m^3 vehicle and minimum emission is occurred as 5.08 kg CO_2-eq while using natural gas in 13+1,5 m^3 truck. Contrary to expectations, kg CO_2-eq / ton value (which is show the GHG emission rate) is decrease while the engine power (horsepower) increases. It has been determined that there are significant differences in GHG emissions when the truck and/or fuel type are changed, even without changing factors such as route, waste collection frequency and number of stops (number of containers). When our study and previous studies are examined there is no specific value for emissions during waste collection .

Besides that studies in the United States have shown, researches are mostly focus on reducing emissions by the development of new technologies and the use of new fuel types in trucks. However recently it is realized that the driver's behavior have a significant impact on the emissions . For instance in Istanbul, as a result of smart driving techniques and fuel efficiency studies, Istanbul Electric Tramway and Tunnel Establishments reduced fuel consumption by 3.575.944 liters in 2013 (İETT, 2013). Emission release from total CO_2 has decreased from 246.169 to 234.710 between 2012 and 2013 (İETT, 2013).

CONCLUSION

In conclusion during waste collection in a route, there is an inverse proportion between the amount of fuel consumed and the population concentration. For example; fuel consumption for unit (ton) waste is higher in the rural areas than in the city center because of the population density in the rural areas is less than the urban areas . Only fossil fuels are compared in this study. The same study can be done in the electric vehicles which have been increasing rapidly in recent years. This study was carried out only in consideration of the operational stage, and further studies can be carried out in consideration of both fuel and truck production LCA’s.

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