Comparative analysis of exhaust gases from MF285 and U650 tractors under field conditions

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Abstract: Agricultural machinery is an important source of emission of air pollutant in rural locations. This work deals with the effects of types of tractors and operation conditions on engine emission. The values of some exhaust gases (HC, CO, CO_2, O_2 and NO) from two common tractors (MF285 and U650) at three situations (use of ditcher, plowing and cultivator) were evaluated in the West of IRAN (Kermanshah). In addition, engine oil temperature at operation conditions was measured. Also results showed the values of exhaust HC and O_2 of MF285 are lower than U650, while the other exhausts gases (CO, CO_2, and NO) of MF285 are higher than U650. Value of NO emission increased as engine oil temperature increased. All of exhaust gases except CO have a significant relationship with type of tractors, while all of measured gases have a significant relationship with installed instruments at 1%.

Keywords: environmental pollution, exhaust gases, tractor

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1 Introduction

Air pollution is a serious problem in all over the world. Diesel engines seem to have a large influence on air pollution because they are used for heavy-duty trucks and emit a higher level of pollutants than petrol engines do, however diesel fuel has slightly higher energy content than petrol per unit volume. Off-road vehicles, trucks, buses and other types of heavy-duty vehicle are powered almost exclusively by diesel engines. Diesel engines make a significant contribution to air pollution (Lindgren and Hansson, 2002).

Many studies have been conducted concerning diesel emission analysis and reduction techniques (Jacobs and Assanis 2007; Felsch et al., 2009; Teraji et al., 2009). Pollutants from diesel engines can be roughly divided into groups (Heywood, 1988). The first one is NO_x. NO_x mainly consists of nitrogen oxide (NO) and nitrogen dioxide (NO_2). The concentration of NO in diesel exhaust is higher than that of NO_2; however, NO_2 has much higher toxicity than NO does. In addition to these two species, N_2O has been recently gathering attention because of its 200 times higher impact factor than carbon dioxide on global warming (http://www.Ipcc nggip. iges.or.jp/public/). Although it can be said that NO, NO_2, and N_2O have different impacts on the environment. The most studies of diesel engine exhaust introduce them as the same species, which is named just NO_x.

The second element of diesel exhaust is hydrocarbons and CO. Hydrocarbons consist of thousands of species, such as alkanes, alkenes, and aromatic. Although their toxicity, carcinogenicity, and impact of oxidant formation vary from species to species, they are usually treated together as total hydrocarbons (THC) (ACGIH Website). These uniform treatments of NO_x and THC have arisen

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for two reasons. The first one is that the exhaust gas of automobiles is regulated only by levels of NO_x and THC. Another one is the difficulty in measurement. Usually, an analysis of engine exhaust is performed by gas chromatography–mass spectrometry (GC–MS) (Borras et al., 2009). However, achieving quantitative analysis takes a long time. Real time measurement is desirable for engine exhaust analysis because the exhaust gas composition changes in real time along with changes in the engine operating conditions. However, Performing GC-MS in real time is difficult. For these reasons, only a few studies were done about the details of exhaust gas compositions and the effects of engine operating conditions on the compositions (Schulz et al., 1999; Gullett et al., 2006).

The last element of diesel exhaust is particulate matter (PM), which is important to diesel engine exhaust. PM is usually measured by weighing a filter which was exposed to exhaust gas and trapping PM. In a study it is suggested that Nano-particles, generally having a diameter of less than 100 nm although there are different definitions, are more hazardous to human health than larger particles. The standard filter weighing method is regarded as less sensitive for such small particles. According to this reason, the European Commission decided to adopt a new PM measurement technique for automobiles. It is the number counting method, in which the numbers of particles from 23 nm to 2.5 μm are counted. This method has a higher sensitivity to small particles than the standard filter weighing method, because small particles and large particles are treated equivalently (Kittelson, 1998). This discussion indicates that it is important to know the size distribution of particle emissions.

According to an analysis by the Health Effects Institute(HEI, 1995), the composition of diesel exhaust varies considerably depending on engine type and operation conditions, fuel, lubricating oil, and whether an emissions control system is present.

An important proportion of the diesel engine emissions causing environmental problems is caused by work machinery such as agricultural tractors and forestry machines (Hansson et al., 2001). Exhaust emissions from agricultural tractors have a detrimental impact on human health and the environment. In order to reduce these emissions, standards have been introduced and are continuously being tightened (EU 2000, 2004, 2005; Larson and Hansson, 2011). These standards only concern existing vehicles. The latest studies (Hansson et al., 1999) have shown that emission values for agricultural tractor operations cannot be reasonably accurately calculated from average emission factors without account being taken of the type of load on the engine in the operation performed. Large variations in emissions were found between different operations, even when the emissions were related to the mechanical energy output of the engine (emissions in g kWh^{-1}).

Further, there is a great need for precise data on total emission production, for example in processes deciding emission rights and pollution taxes. It is therefore very important that average loads on engines can be decided with high precision. With good knowledge of the average load on a tractor engine, it will also be possible to optimize the engine more effectively in order to minimize the total emissions. The previously described large differences in emission values among different operations indicate that the typical use of the tractor may have important effects on average emission factors. The average use of tractors is related to many more factors than engine size, for example, farm size and its production policy, and the size and age of the other tractors on the farm (Biller and Olfe, 1986). The largest tractor on the farm is normally used for the heavier operations, e.g. soil tillage, while the other tractors are more often used in lower load operations. It is, therefore, also important to investigate whether the average emission factors differ between tractors of the same size, but with different average use (Hansson et al., 2001).

Recently, many researchers focused on exhaust gases of diesel and petrol engine, such as a comparison between different methods of calculating average engine emissions for agricultural tractors evaluated by Hansson et al. (2001). Environmental impact of catalytic converters and particle filters for agricultural tractors determined by life cycle assessment investigated by Larsson and Hansson (2011), simulated farm fieldwork, energy consumption and related greenhouse gas emissions in Canada by Dyer and Desjardins (2003), effects of vehicle type and fuel quality on real world toxic emissions from diesel vehicles were investigated by Nelson et al. (2008). Emissions from heavy-duty vehicles under actual on-road driving conditions were measured by Durbin et al. (2008). Detailed analysis of diesel vehicle exhaust emissions, nitrogen oxides, hydrocarbons and particulate size distributions were obtained by Yamada et al. (2011). Gaseous and particulate emissions from rural vehicles in China were measured by Yao et al. (2011), etc.

Therefore, the purpose of this work was to measure average some exhaust gases values such as hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2) and nitrogen oxide (NO) from different tractors at three operations conditions. Engine oil temperature was measured too.

2 Materials and methods

The aim of this study is the measurement and correlation between some exhaust gases from two common and popular tractors (MF285 and U650) in IRAN at three situations (use of ditcher, plowing and cultivator operations). The data was recorded in the field with 6,500 m^2 area and clay-loamy soil. Tests by every implement were done in four replications. The operations were done at autumn tillage.

Table 1 shows specifications of the tractors was used. The operation conditions were considered for this study and instruments specifications were shown in Table 2. As is shown in Figure 1 ditcher, moldboard plow and cultivator were used. The tractor speed in every operation selected from standard method (ASAE D497.4 MAR99).

Table 1 Specifications of the Tractors

	Class	Model	Number of cylinders	Fuel type	Engine operating process	Engine power /hp
Tractor 1	MF 285	1984	4	Diesel	4 - Stroke	75
Tractor 2	U650	1985	4	Diesel	4 - Stroke	65

Table 2 Specifications of the instruments and operation conditions

Types of instrument	Characteristics	Engine speed/r min^{-1}	Tractors speed/km h^{-1}
Ditcher	Moldboard ditcher	2250	8
Plowing	Three bottom moldboard plow	22 0	5
Field Cultivator	Nine tine cultivator	2250	8

a. Moldboard plow

b. Ditcher

c. Cultivator

Figure 1 Implements

FGA-4100 automotive emission analyzer made in China was used for measurement of exhaust gases and engine oil temperature. The details of specific device are illustrated in Figure 2. As is shown in Figure 2 exhaust gases enter to five gas analyzer without dilution. The flow ratio of the exhaust gases is changed by changing the engine speed, so the dilution ratio varied with changing engine speed. Patterns of driving could affect vehicle emissions significantly, so they are very important in measuring vehicle emissions (Hansen et al., 1995; Kean et al., 2003; Yao et al., 2007). Therefore, for solving this problem, engine speeds stabilized during operations with hand accelerator. Then engine speed stabilized at 2,250 r min^{-1}.

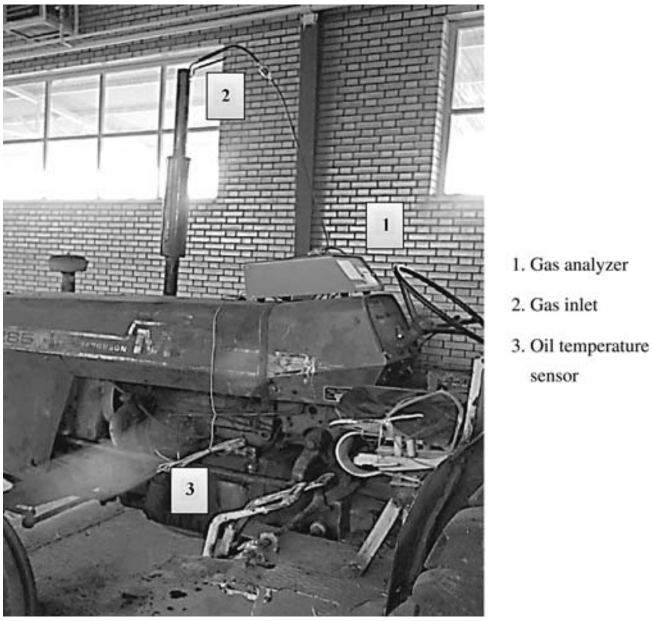

Figure 2 Details of specific device

Fuel and lubricating oil were constant in both of tractors at every operation, because these parameters are effective on engine emission (HEI, 1995). Both tractors are equipped with the same instruments and worked at the same conditions and measured exhaust gases.

3 Results and discussions

In this research we focused on details of exhaust gases from two common tractors that are used in IRAN at three operation conditions. All of the obtained emission results are presented in Table 3, Table 4 and Table 5. As is shown in these tables measured CO, CO_2 and NO emission from MF285 are higher than U650; however HC and O_2 from U650 are higher than MF285.

Table 3 Exhaust gases at ditcher operating.

	MF 285			U650		
	Max	Min	Average	Max	Min	Average
HC/ppm	45	41	43.2	97	65	81.2
CO/%	0.14	0.12	0.13	0.2	0.06	0.11
CO_2/%	8.6	7.5	8.02	3.7	1.1	2.38
NO/ppm	470	271	362.6	105	13	34
O_2/%	12.9	10.8	11.7	18.4	13.8	16.46
Engine oil temperature/°C	68	63.4	65.58	96.3	70.02	70.9

Table 4 Exhaust gases at plow operating

	MF 285			U650		
	Max	Min	Average	Max	Min	Average
HC/ppm	49	46	47.75	95	67	82
CO/%	0.27	0.11	0.16	0.2	0.11	0.15
CO_2/%	10.3	7.8	8.92	6.7	3	5.15
NO/ppm	523	369	431	155	43	119.5
O_2/%	11.7	9.92	10.70	17.8	12	13.87
Engine oil temperature/°C	66.5	62.3	64.35	62.3	59.2	60.57

Table 5 Exhaust gases at cultivator operating

	MF 285			U650		
	Max	Min	Average	Max	Min	Average
HC/ppm	66	41	45.1	76	58	66.75
CO/%	0.16	0.11	0.13	0.1	0.06	0.08
CO_2/%	9.8	7.1	8.34	3.8	1	2.2
NO/ppm	560	228	365.8	129	20	68.25
O_2/%	13.6	9.08	11.40	18.7	14.4	16.58
Engine oil temperature/°C	54	46.2	51.2	75.3	71	73.77

3.1 HC emission

The measured HC values in both tractors in three operating situations are shown in Figure 3. Results showed the value of HC emission while plowing by tractors is higher than the other condition. In addition, the values of exhaust HC from U650 are higher than MF285 at every three operations. The results of variance analysis showed that amounts of exhaust HC have a significant relationship with types of tractors and instrument at 1% as shown in Table 6.

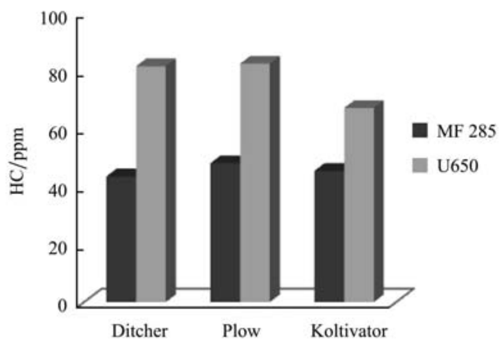

Figure 3 HC emission from tractors at operation conditions

3.2 CO emission

The amount of measured gases in both of tractors showed the value of exhaust CO as well as other diesel engines is very low in comparison with petrol engine (DEFRA, ACE Information Programme, Air pollution and Rain Fact sheets Series: KS4 and A). The recorded data showed values of CO in plowing operation are higher than other operations. CO emitted from U650 is lower than MF285 (Figure 4). The results of variance analysis (Table 6) showed that amounts of exhaust CO don't have a significant relationship with types of tractors, but they have significant relationship with types of instrument at 1%. Therefore, values of CO emission are independent from types of tractors.

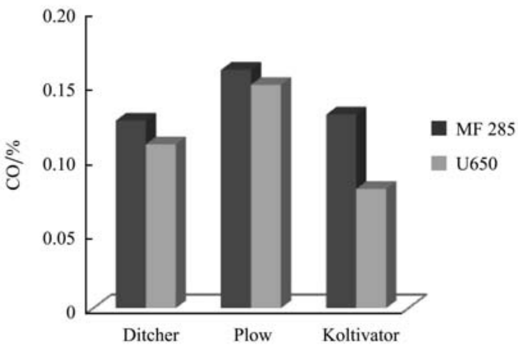

Figure 4 CO emission from tractors at operation conditions

Table 6 Variance analysis

	Tractor			Instrument		
	Mean Square	F	Significant Level	Mean Square	F	Significant Level
HC	1170.40	427.21	0.01>	7.95	0.017	0.01>
CO	0.125	26.89	0.01<	0.006	3.04	0.01>
CO_2	204.34	138.76	0.01>	2.16	0.155	0.01>
O_2	28.64	22.06	0.01>	2.03	0.20	0.01>
NO	139919	105.99	0.01>	2614	0.056	0.01>

The recorded data of CO_2 showed values of this gas at plowing operation are higher than other operations. CO_2 emitted from U650 is lower than MF285 as is shown in Figure 5. The results of variance analysis showed that amounts of exhaust CO_2 have a significant relationship with types of tractors and instrument at 1% (Table 6). Therefore values of CO_2 emission are dependent on types of tractors and instrument.

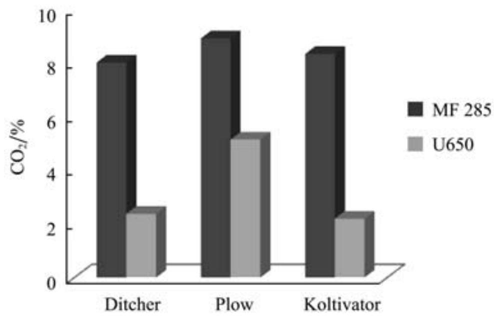

Figure 5 CO_2 emission from tractors at operation conditions

3.4 O_2 emission

The recorded values of O_2 showed amounts of this gas at cultivator operation are higher than other operations and O_2 emitted from U650 is higher than MF285 (Figure 6). Results showed that exhaust O_2 from both of tractors had an inverse relationship with the NO, CO, CO_2 as shown in Figure 7. The results of variance

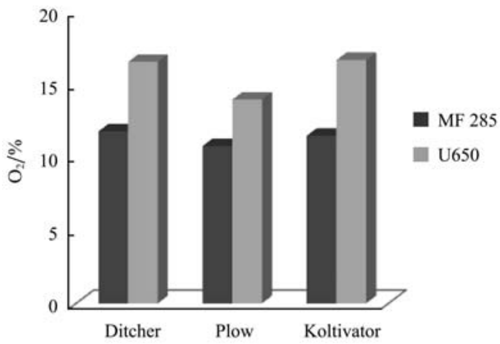

Figure 6 O_2 emission from tractors at operation conditions

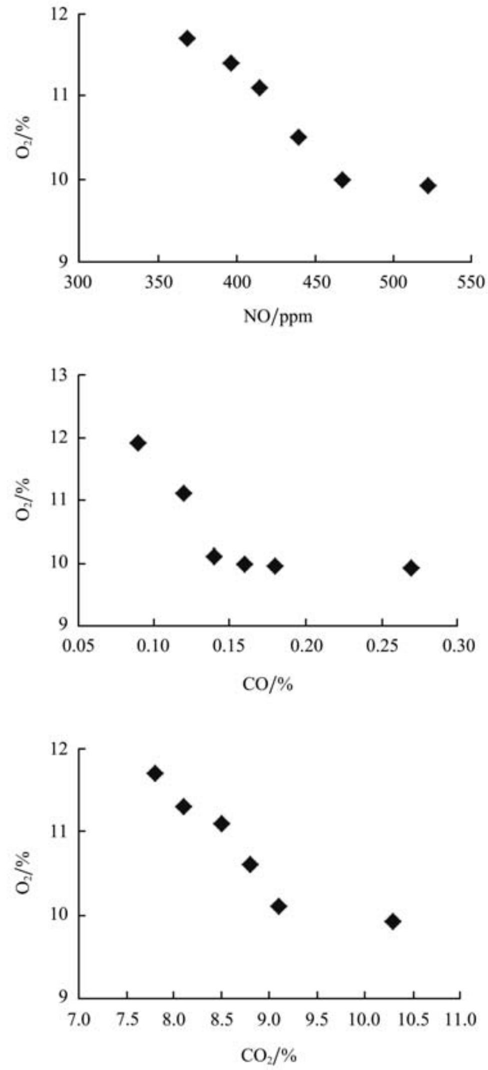

Figure 7 Relationship between exhaust O_2 and other exhaust gases

analysis showed that amounts of exhaust O_2 have a significant relationship with types of tractors and instrument at 1% (Table 6). Therefore, values of O_2 emission are dependent on types of tractors and instrument.

3.5 NO emission

The experimental data of NO showed values of this gas at plowing operation are higher than other operations (Figure 8). As is depicted in Figure 9, in each tractors NO emission increased as the engine oil temperature increased. Also, the mentioned result was reported for the relationship between NO emission and in-cylinder temperature by Yamada et al. (2011). In addition, NO emission increased by loading enhancement on tractors, therefore NO emission in plow operation was higher than the other conditions. The results of variance analysis showed that amounts of exhaust NO have a significant relationship with types of tractors and instrument at1%. Therefore, values of NO emission are dependent on types of tractors and instrument.

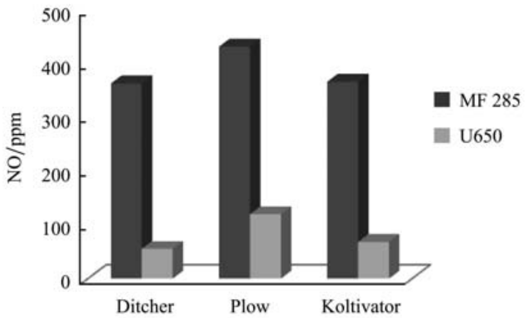

Figure 8 NO emission from tractors at operation conditions

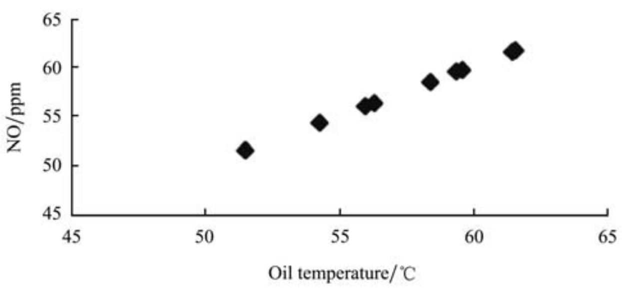

Figure 9 Relationship between NO emission and engine oil temperature

3.6 Engine oil temperature

The recorded values of engine oil temperature showed amounts of this gas at cultivator operation are higher than other operations (Figure 10).

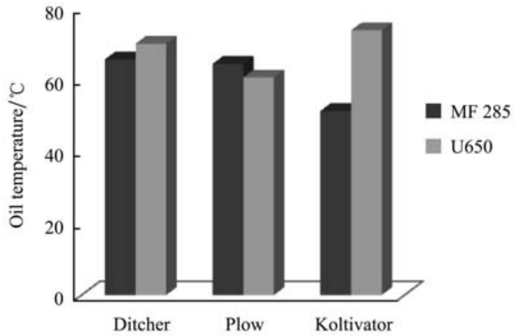

Figure 10 Engine oil temperature at operation conditions

4 Conclusion

Evaluation of exhaust gases from diesel engine is important. In this study emission from two current tractors in IRAN at three operation conditions (using ditcher, plowing and cultivator) was reported. Some exhaust gases (HC, CO, CO_2, O_2 and NO) and engine oil temperature were measured.

HC and O_2 emission from MF285 were lower than U650, while other emission (CO, CO_2, NO) from MF 285 were more than U650. Emission from tractors like other diesel engines, value of exhaust CO is very low in comparison with petrol engines. NO emission increased as engine oil temperature increased. All of exhaust gases except CO have a significant relationship with types of tractor and instruments at 1% as is shown in Table 6. This subject was presented by Durbin et al. (2008), for NO emission from heavy-duty vehicles.

The values of all measured gases at plow operation are higher than the other operations except O_2. It can be clearly seen that amount of exhaust gases depends on amount of loading on tractor. As is shown in Figure 3, Figure 4 and Figure 7 amount of exhaust CO, CO_2 and NO from U650 is lower than MF 285. Therefore used of U650 suggested for agricultural operations, because emission from U650 are lower than MF 285.

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