COMPARING THE CARBONDIOXIDE EMISSION RATES DUE TO ROAD TRANSPORTATION WITH EXPECTED VALUES

Extended Essay: Chemistry
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Abstract:

Today, the circumstances in our world are not so optimistic. The main problem nowadays is environment's negative development such as global warming. Energy demands of people increase each day and this cause humans to forget their living places' conditions. Ironically, the problem shaping in a way that the world, where human being lives becomes the problem itself because of wrong actions of human. We burn a lot of fossil fuels since industrial age, and now, main purpose of burning fuel is energy demand. The need for travelling and using cars are included.

In this essay, the development level of Turkey, when the emissions coming from road transportation are considered, would be investigated in a methodological way. By the way, the essay purposes to answer the question, which is, how many of the CO_2 emission due to road transportation should be prevented. Most of the study is formed by statistical data, so it gives an opinion to the reader but not the exact result. This does not mean that the essay is not reliable, because the results would be near the real values.

Lastly, the essay is only considering the CO_2 emissions, not the other greenhouse gases, so it gives a specialised information to the reader about the subject, not a general point of view.

Contents:

INTRODUCTION

During the period from 1905 to 2005, the average temperature values of the world increased by $0{,}74\,^{\circ}C$ $(\pm 0{,}18)$ [1].The increase in the average temperature of the world is related with the human made greenhouse gases. IPCC (Intergovernmental Panel on Climate Change) stated this as most of the observed increase in the globally averaged temperatures since the mid-twentieth century is very likely due to the observed increase in manmade greenhouse gas concentrations".

To continue with, there are some climate models which are considering the situation,what happens if process of burning fossil fuels continues with an increasing rate. IPCC reflects that the average global warming would be increased between $1{,}1\,^{\circ}C$ to $6{,}4\,^{\circ}C$ according to some climate models[2].These values reveal that consequences of burning fossil fuels has a variety of decent events. One main one is the increase in the sea levels. Even if the greenhouse effect is stabilized, increase in the sea levels would continue for a while since the heat gaining or losing of water is a long term process due to the heat cappacity of it. This increase means decrease in the amounts of ice at the poles, and a new mechanism arise from this situation. This mechanism is called "ice-albedo" feedback[3].The increase in the global temperature causes ice on the poles to melt. Ice is an important element when dealing with global warming. They reflect the sunlight to the space without letting them to heat the world. Because of it, the melting of ices increase the rate of global warming since water is not as effective as isces at reflecting sunlights. Again, the increase of global temperatures cause more ice to melt. This increasingly continuous process is called "ice-albedo" feedback.

Another feedback mechanism is also present related to global warming. Increase in the amounts of greenhouse gases causes an additional increase in the rate of global warming again. The result of this positive feedback is simply; the more air temperature near the ground increases, the more water is evaporated. Since water vapour is also a greenhouse gas, this process causes global warming to develop further[4].

As it is seen in the mentioned mechanisms of greenhouse effect, it is understood that the main cause of this effect is that there are more greenhouse gases than it should be, and the biggest problem in the world is how to cope with this problem.The very first way of this struggle is to decrease the amounts of greenhouse gas emissions systematically. All of the greenhouse gasses are included to this statement, however; at this point, the consideration should be that, which of the greenhouse gases have priority, which means which have the greatest effect on global warming.

At this point of view, CO_2 has the priority. The reason of choosing CO_2 is, firstly, it is produced nearly in all of the energy production processes. This means it is one of the most

[1] *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.*
[2] *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate*
[3] *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate*
[4] Soden, Brian J.; Held, Isacc M. (2005). An Assessment of Climate Feedbacks in Coupled Ocean-Atmosphere Models

effective greenhouse gas that is produced massively due to the actions of humans. The sources of CO_2 emissions are so varied. That is why, CO_2 is main product of burning reaction and one of the main elements of life cycle. Even individually, people burn at least several liters of fossil fuel each day. Also, our oxygen sources, plants are producing CO_2 for gaining energy.

On the other hand, CO_2 is not the only decent greenhouse gas. Methane is also one of the most effective greenhouse gas in the world, even more effective than CO_2 in theory, however, the concentration levels of methane throughout the world is much more smaller than CO_2, so it's reflective force is equivalent to one fourth of CO_2[5]. The other greenhouse gases have varied effects but they are even less than the reflective effect of methane, so they are not mentioned in this section.

From the examples above, the priority of CO_2 is revealed. At this stage, the matter is that how could countries process against global warming. This requires some serious and systematical progress. Throughout the world, there are so varied emission levels of CO_2 gas, which means the progress against global warming should be valid for all of the countries that have different emission levels. There is a protocol present that includes the requirement which is just mentioned. The name of this protocol is Kyoto Protocol. Since global warming is a global problem, the subject should be taken into consideration with respect to genereal progress. More than 55 countries signed the Kyoto Protocol, so a general investigation on the circumstances in different countries could be made with respect to this protocol.

The subject of this essay is including the effects of road transportation to the global warming. That is why, the essay is based on the criteria in the Kyoto Protocol. There are so many statistics about the levels of emissions of greenhouse gases for the different countries and these levels of emissions could be estimated for the further years with the help of statistics, and a general conclusion could be arise, so the essay also based on the statistical data and also the experiment. The properties of the experiment will be given later. One last thing that should be mentioned is, this essay is mainly considering the situation in Turkey, in which the main transport system is road transport. There are some countries that are producing CO_2 over the average world emission rates and also some of the countries produce less than average. Besides, since the main transportation system is road transportation, it is much more efficient to benefit from such a country while investigating the CO_2 emission rates due to road transportation.

Up to now, the included issues into the essay are mentioned. However, these are just sub-issues that helped the essay to develop. The target of this essay is to answer the question, which is; "Are the emission rates of CO_2 in Turkey due to road transportation acceptable in order to prevent global warming to develop further". In addition to this, the word "acceptable" means acceptable according to Kyoto Protocol, and the emission rates are concerning the situation in road transportation.

[5] Kiehl, J. T.; Kevin E. Trenberth (February 1997). Earth's Annual Global Mean Energy Budget

HYPOTHESIS

Although there is a similar gas to CO_2 present, which is methane, it is understood that it has less effect on global warming, so CO_2 has the most decent effect on athmospherical warming shield. It is produced widely throughout the world and it is the lead gas of global warming effect. As it is impossible to survive without global warming, it is also harmful to our world when the CO_2 levels are increased. The levels of the carbon dioxide gas threatens the world and people are aware of it. Therefore, they are putting some new systematical projects to decrease the levels of CO_2.

The processes of the countries should be investigated seperatedly under a hypothetical study. Since this essay is concerning the situation in Turkey, the hypothesis of this essay is, ***"the emission levels of cars in Turkey are not acceptable for preventing global warming and the*** CO_2 ***emission levels due to cars should be decreased by %50."***

METHOD DEVELOPMENT AND PLANNING

In order to gain successful results, developing an appropriate method for the process is essential. To support or reject the stated hypothesis, the method should give some solid evidences and must be reliable. Because of these criteria, choosing a suitable method becomes more challenging. Also, there are some problems to deal with too.

First of all, it is needed to find the number of cars present in Turkey. It is impossible to count all the cars one by one in any country since the numbers of cars are astronomic in today's world, so statistical data is needed when calculating the emission levels. This situation also arise a new issue, which is that the source of statistical data should be reliable, accurate, up-to-date and scientific. This kind of a source is present on the internet, which is the statistical data department of the European Comission, "Eurostat". There are various kinds of statistical data on number of cars in Turkey. The data in the website of Eurostat are reliable, since the organisation is based on a official commission. Besides, the data are scientific and accurate as they are found by methodical applications and they are up-to-date. After all, the number of cars in Turkey are able to found and the results are stable and suitable for realistic approximations on the emission levels due to cars.

Another problem is that, there are various kinds of cars that some of them are burning less fuel while some of them burning more. This situation would clearly affect the results gained from the process so an appropriate method for solving this issue should be found. The car producers are making emission tests of carbondioxide just after they produce a car. These data is for only one kind of car, however, if the emission values of several types of cars that are present in Turkey are taken into consideration by taking the average values of all, the result would become more stable. At this point, there comes another problem, which is the choice of the cars whose average emission values would be calculated. These cars should be chosed as; one group should include the ones which burn fuel more than general burning levels, and the other two groups should be including the cars which burn fuel less than the general levels and the ones which burn average values of fuel. Also, the number of data should be arranged properly, which means that there should be more of the cars that burn

average levels of fuel and there should be less number of data which consider the other two groups. The reason for that is the structure of traffic in Turkey states there are more of the average fuel burning cars in Turkey.

Moreover, as the fuel burning levels are showing the values in liter, the level of the carbondioxide in one liter of fuel should be found. This is also needed as the essay tries to compare the amounts of carbondioxide and it is necessary to translate the values of CO_2 in million tons. This is possible if CO_2 value in a unit liter of gasoline is found properly. First of all, an experiment should be made in order to measure the CO_2 levels in exhaust gas. This experiment is basically as same as the standard emission level measurement executed in the car services. An electronic equipment is placed in the exhaust pipe and it measures the CO_2 levels and the other gases that are not in our consideration as mentioned in the introduction.

The other fact is that, different cars should be used to measure the emission values average values of the gained data should be used. The reason is that, there are variety of cars in Turkey that produce different levels of CO_2 as mentioned in previous paragraphs.

However, the measurement only gives us the volume of CO_2 in exhaust. By the way, we have the data that we know the volume of carbondioxide per liter. It is useless since global comparament of emission levels are in units on million tons and hence, the data gained in experiment should be translated into million tons.

The volume of one liter CO_2 in standard conditions are known. If the chemical terms such as molarity and the principles on gases are applied on the data, it is possible to find the mass of CO_2 that are arise after burning fuel. From now on, the steps should be proceed in such a way that more statical values must be used. Because of this, the reliability of statistical material is essential.

The main problem at this point is that, the data that are collected after some mentioned calculations are not enough to calculate general emission level of CO_2 due to road transportation. First of all, the amount of fuel that is burned in one kilometer should be found. The car producers have found to be measured the amount of burned fuel in liters. This data is used in a way that when multiplied by the emission levels of CO_2 per one liter in kilograms, the amount of emission in one kilometers are found.

Besides, calculating the annual emission of CO_2 due to road transportation requires the number of kilometers that one car travels in one year. This issue needs most of the statistical work. It is impossible to reach certain results however, some estimations could be made. Best way of reaching the considered value is to benefit from an independent source. This could be several other countries. There are some criteria when choosing the appropriate countries, such as the conditions. In Turkey, the main transportation network is road transportation, so the countries that are going to be choosed must have the same conditions. Of course, it is not possible to find fully appropriate country under this criterion, so another one is needed such as the emission levels of cars that are used in the country should be similar. After all, the choosed countries are Belgium and England.

The emission levels in these countries are measured by reliable sources such as Eurostat, so the number of kilometers that one individual car travels is able to calculate. The emission values due to road transportation should be divided into the number of cars in these countries. After that process, the amount of CO_2 that belongs to one car in one year are found in the unit of kilometers. Also, this value should be divided into the emission value of one car in one kilometer. These steps are a little bit confusing because of similar terms, however, the number of kilometers that an individual car travels are found. Since the two country are used in this process, the average values for both of them should be found after.

From now on, the useful part of the essay comes. Firstly, the comparement of two situations in Turkey, requires some fundamental support. The Kyoto Protocol is this supportive document. The statement in 3rd article is about expected development level for countries that have signed. As it generally states that the countries should decrease their emission levels %5 cent below the emision levels in 1990, the conclusion of this essay should be comparing two situations. The situation in 1990 is not easy to calculate, so the data would be taken from Eurostat also. It is hard to develop a model for he situation in 1990, as lot of facts have been changed since 1990. This essay only considers the road transportation, and just like road transportation, emissions due to energy demand have been changet totally, so the results would not be reliable if a basic model is tried to be developed.

The developed method is now giving us the opportunity to calculate and compare emission levels in 2008 and 1990.

MATERIALS AND METHOD

Materials:

1)One Honda Civic Sedan 1.6L Dream with gasoline
2)One Volvo S40 1.6L with gasoline
3)One Hyundai Accent Sedan with gasoline
4)One Volkswagen Passat 1.6L with gasoline
5)One Nissan 350Z with gasoline
6)One Ford Focus 1.6L Duratec with gasoline
7)One Peugeot 308 SW 1.6L with gasoline
8)One exhaust emission measurement computer
9)Exhaust emission measurement pipe

Method:

(This essay is mainly based on statistical calculations, but not everything could be obtained from statistical data. By the way, the experiment should be done and it is outlined a little in method development part of the essay)

PART A: Collecting data from the cars

After placing the cars respectively, exhaust emission measurement pipe should be placed into the exhaust pipe and the space between measurement pipe and exhaust pipe should be isolated. This isolation step is important for reliability of the experiment. After that, the data output from the computer should be printed. All the measurement steps should be repeated for each car by noting which values refers to which car. Lastly, the measurement process shold be made under normal conditions. The data shows the level of CO_2 arised in each car's unit liter of fuel.

PART B: Processing the data with statistical data

The values of the CO_2 percentage in one liter of gasoline are found from the experiment. On final, the CO_2 emission levels in million tons should be obtained, so the values in liters are not useful. Since the volume of gases are known under room temperature amd 1 atm, molarity of CO_2 could be found. From the equation, P.V = n.R.T, where n represents the mole number of substance, P represents pressure, R is constant, T is temperature and V is the volume. V could be found from the experiment, as it shows the percentage of CO_2 in a liter fo exhaust. One mole of any gas under room temperature and 1 atm pressure is same for all, and is known, it could be answered that how many moles of CO_2 gas arised. By simple proportion (V1.x = V2) where v1 represents the volume of all gases which are 1 mole and under room temperatures, and x represents the mole number of the gas thatis obtained from the experiment and v2 symbolises the volume of gas that is also obtained from the experiment. Furthermore, the mass of one mole CO_2 is known, so if it is multiplied by x value, mass of CO_2 could be obtained when 1 L of fuel is burned. These steps should be replied for each car. Then, how many liters for travel of one kilometer is needed should be found. Car producers have already measured the emission levels (in liter) per 100 kilometers

of travel, so the values should be divided to 100. For all of the cars, there are different values, so these should also be taken as average values. Just after, the amount of CO_2 arised from 1 kilometer of travel, it should be found that how many kilometers does an individual car travels in one year.

To answer this question, it should be beneficial to use two countries that are independent from the subject. These are Bulgaria and Belgium. The values of emission levels due to road transportation for both countries are present on Eurostat's archive, and also, the amounts of gasoline burning vehicles are also present. If the amount of CO_2 due to road transportation is divided into the number of vehicles, CO_2 amounts due to an individual car should be found. Then, since two countries are used, the value should be taken average. The amount of arised from burning fuel after travelling 1 km have already found in previous steps, so if CO_2 amounts due to an individual car is divided into this value, the annual kilometers that an individual car travels should be found out.

Then, if the amount of cars in Turkey are multiplied by the value found in previous paragraph, the amount of CO_2 due to road transportation is found in million tons. Then, this value is suitable for comparing with the numbers in 1990 and a reliable comparament could be made.

DATA COLLECTION

	1st Result (L) (±0.05)	2nd Result (L)(±0.05)	Mean (L) (±0.1)
Hyundai	%15.74	%16.20	%15.9
Peugeot	%14.62	%13.76	%14.1
Honda	%11.49	%13.96	%12.7
Volkswagen	%15.49	%14.32	%14.9
Nissan	%20.24	%19.33	%19.7
Ford	%14.10	%14.82	%14.4
Volvo	%17.26	%17.12	%17.1

Table 1: reflects the values gained from the experiment. They are the volume of CO_2 in one liter of fuel that is burned in each car.

Honda Civic Sedan 1.6L	6.7 L
Volvo S40 1.6L	7.1 L
Hyundai Accent Sedan	7.6 L
Volkswagen Passat 1.6L	7.6 L
Nissan 350Z	11.7 L
Ford Focus 1.6L	7.7 L
Peugeot 308 SW 1.6L	6.4 L

Table 2: shows how many liters of gasoline does that each car burn for 100 km of travel. These values are stated by producer of the cars respectively.

	Number of Cars	Amount of CO_2 due to road transportation (million tons)
Bulgaria	2393700	7.620
Belgium	5814000	25.80

Table 3: reveals the number of cars in England and Belgium and also the amount of CO_2 arised due to road transport. These values are taken from the foundation, Eurostat.

Calculation of volume of CO_2 in 25°C (298 K) and 1 atm:

Mass of 1 mole CO_2 = 44.0g (According to periodic table)

density = (molar mass x Pressure) / (R x Temperature)
= (44.0 x 1 atm) / (0.082 x 298)
= 1.80 g/L

density = mass / volume
1.80 = 44.0 / volume
Volume of 1 mole CO_2 = 24.44 L

DATA PROCESSING

1) The amount of CO_2 arised in one liter of gasoline burned should be found.

	L (±0.1)
Hyundai	15.9
Peugeot	14.1
Honda	12.7
Volkswagen	14.9
Nissan	19.7
Ford	14.4
Volvo	17.1

Table 4: shows the mean values that are also shown in Table 1. These are needed for the further step.

Mean of the values in Table 4: 108.8 / 7 = 15.5 L (±0.7)

These values should be translated into mass in kilograms. Firstly, their mole numbers are needed:

1 mole CO_2 = 24.4 L

15.5 / 24.4 = 0.6 mole

1 mole CO_2 = 44.0 grams

44.00 x 0.6 = 28.0 gram of CO_2 arises after 1 L of gasoline in general.

2) How many liters of gasoline does each car burn for 1 km of travel, should be found.

Honda	0.067 L
Volvo	0.071 L
Hyundai	0.076 L
Volkswagen	0.076 L
Nissan	0.117 L
Ford Focus	0.077 L
Peugeot	0.064 L

Table 5: The values in this table relate the amount of fuel that each car burns after 1 km of travel. These values are gained by producers.

Mean of the values: 0.078 L

-The two values that are found in 1st and 2nd steps should be multiplied in order to find how many grams of CO_2 are arised after travelling 1 km.

0.078 x 28.0 = 2.2 g CO_2 per kilometer

3)At this point, by the help of two countries that are independent from the subject, annual travel of an individual car should be estimated.

For Bulgaria: 7,620,000 tons of CO_2 are arised due to road transportation.

There are 2,393,700 cars present.

For one car, 7,620,000 / 2,393,700 = 3.183 tons of CO_2 are arised.

This is equal to 3,183,000 grams of CO_2.

-If this value is divided by the value; which shows the amount of produced CO_2 in one kilometer of travel, the hypothetical estimation of number of kilometers that a car travels is found.

3183000 / 22 = 1446980

For Belgium: 25,800,000 tons of CO_2 are arised due to road transportation.

There are 5,814,000 cars present.

25,800,000 / 5,814,000 = 4.437 tons of CO_2 are arised.

4,437,000 / 22 = 20,170

Mean value should be taken: (14.469 + 20.170) / 2 = 17319 km per year

This is the main hypotetical estimation.

4)The estimated "km per year" value should be multiplied by the number of cars in Turkey, which is 6,683,332

6,683,332 x 17,319 = 115,748,626,908

115.75 x 2.2 =254.65 grams of CO_2 produced.

This is equal to 254.65 million tons.

In 1990, number of cars is 2,409,000

2,409,000 x 17,319 = 41,721,471 grams of CO_2 produced.

This is equal to 0.0417 x 2.2 = 0.091 million tons

If two values are compared according to Kyoto Protocol, the result is as shown:

0.091 x %95 = 0.086 million tons that the emission rates should be.

This means the amounts of CO_2 emissions due to road transportation should be decreased by %99.97.

EVALUATION

This essay's main target is to compare the CO_2 emission rates in 1990 and 2008, so this kind of a work brings some reliability problems with it. It is impossible to count the number of cars in each country, so statistical research is setting up the main part of this essay, however, there is an experiment made that establishes the integration between statistics and real life. By the way, the result becomes more accurate. Also, there is a slight change that is made in the data processing part, which is, while calculating the value of how many kilometers does an individual car travels. The value, 2,2 is changed into 22 because there could be additional process of burning fuel while the cars are stopping in urban areas, and waiting for the lights or the other reason is that the traffic flow in cities are slow, so more fuel than expected are being burned. To prevent astronomical numbers of travelling rate of cars, this change is made. Otherwise, the cars would shown as travelling more.

Another important thing is that, dot (.) symbol and comma (,) should be distinguished from each other. The comma is used to prevent confusion while dealing with huge numbers, while the dot is just symbolising there are decimals coming after the number that is written. It should be reflected, because it could lead to confusion since the numbers in the essay are huge..

If the results are considered, the amount of CO_2 produced by burning a liter of gasoline is giving the values that are similar to car producers' values, which shows the experiment is a successful one. On the other hand, the amount of produced CO_2 due to road transportation is a little bit different from the ones in statistical archieve of Eurostat. This would probably be because of the differences in methods for collecting and estimating data. However, it is not so effective for the results since all of the data are processed throughout the same methodical pathway, so again, the results are reliable in a way.

CONCLUSION

According to the hypothesis, the CO_2 levels produced by road transportation should be decreased by %50 in order to fulfill the conditions of Kyoto Protocol, however, after the processes that are made during the essay, it is found out to be the correct decreasing level of CO_2 due to road transportation should be %99,97. After all, the result reflects that there should be more strict restrictions such as limiting the usage of cars or developping efficient urban traffic systems. For example, in bigger cities, even short distances are travelled by car. This could be prevented by developing intelligent car pathways that electric cars could travel automaticly and let the passengers travel short distances. The rail versions of these systems are present in some airports throughout the world. These kind of systems are essential for preventing harmful effects of global warming.

APPENDICES:

APPENDIX 1: Article 3 from the Kyoto Protocol, that states the level of decrease in overall emissions, which also includes CO_2 emissions due to road transportation.

Article 3
1. The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to ***reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.***

APPENDIX 2:

Time (Year)	Number of cars in Turkey
2008	6683332

Table 1: shows the number of cars in Turkey in 2008. The values are taken from Government's official statistics foundation, " T.C. Başbakanlık Türkiye İstatistik Kurumu".

APPENDIX 3:

Time (Year)	Total number of cars (in thousands)	Number of cars operating with petroleum products (in thousands)
2004	4874	2490

Table 2: represents the number of cars in Belgium in 2004. These values are used when finding the annual travel of an individual car. (Taken from Eurostat)

APPENDIX 4:

Time (Year)	Amount of carbondioxide produced due to road transportation (in millions of tons)
2004	25.80

Table 4: relates the amount of CO_2 emissions due to road transportation in Belgium. (Taken from Eurostat)

APPENDIX 5:

Time (Year)	Number of cars operating with petroleum products (in thousands)
2006	21976.606

Table 5: shows the number of cars in England. These values are used when finding the annual travel of an individual car. (Taken from Eurostat)

APPENDIX 6:

Time (Year)	Amount of carbondioxide produced due to road transportation (in tons)
2006	120527732.90

Table 6: shows the amount of CO_2 emissions due to road transportation in England. (Taken from Eurostat)

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