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Feasibility of Controlling Pollutants in Urban Bus Terminals: A Case Study in Qazvin

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Abstract

Today an important part of environmental study includes the study of air pollution and its sources. Since motor vehicles are one of most important contributors of air pollution in modern cities, a review of how they are utilized is important. One way of reducing air pollution, is by reducing the number of vehicles left idling in standby mode at the workplace. In this paper, we will examine the amount of pollution generated by public transportation buses in Qazvin and provide methods for controlling pollution of these vehicles. We will express that many residual functions of public transportation vehicles are not only unnecessary, but they are not economical and can do damage to the environment. General vehicles terminals are non-moving sources of pollution or contamination. This is another area in which air pollution can be reduced. Finally, we will estimate the concentration and flow of bus pollution. The use of eco-refining and catalytic converters will also be considered during this case study.

Keywords: Air Pollution, Sources of pollution, Terminals, Reduce pollution

1. Introduction

In a large city in which buses are an important part of public transportation, it can be seen that many buses are left idling during the workday. Increasing numbers of vehicles left in this standby mode on a single day are a major factor in the production of pollution. However, with proper training, this trend can be decreased. The best way to reduce pollution is to understand why buses are left idling. There are some legitimate reasons for leaving diesel buses in a standby mode. They include the following:
The system to open and close the doors of a bus works with wind pressure which is supplied by a compressor. The compressor must be used at least every 20 minutes, or else it automatically becomes empty.
Diesel engines generate excessive heat when they are turned on. Thus, it is preferable to leave them on, as opposed to switching them on and off frequently, so as not to generate wasted heat. When vehicles are initially turned on, there is not complete combustion, owing to the fact that the engine is cold. This is a cause of significant pollutants which can be avoided by keeping the engine idling. Bus accessories, including cooling and heating systems, work with the help of the engine. During summer months, many drivers have been observed leaving their buses idling at the bus terminal in order to take advantage of the air conditioning. Likewise, in cold months, they leave their buses in standby mode in order to use the heater to stay warm [1].

2. Important pollutants produced by Bus:

2. 1 Carbon monoxide

This is one of the most common pollutants in the atmosphere. At temperatures above the boiling point (192 ° C), carbon monoxide has no color, no smell, and no taste. Carbon monoxide is not absorbed by water and burns with a blue flame. It comes from many natural sources. It also exists in car exhaust as a result of the incomplete combustion of fuel. The gas that is produced by man is equal to 10 percent of the amount that exists naturally. Approximately 65% of this artificial source of pollution comes from motor vehicles. Consequently, populated urban areas show high concentrations of this pollutant. The daily concentration of carbon monoxide depends on the amount of traffic crossing through the streets. The dispersion of pollutants in a city is dependent on wind direction, speed, turbulence and stability caused by the relatively low speed of moving cars [2].

2.2. Nitrogen oxides

Nitrogen oxides are categorized into eight types, three of which are found in the atmosphere. These three types are nitrous oxide, nitric oxide and nitrogen dioxide. Nitrous oxide is colorless, non-flammable, has no smell, and is non-toxic. Nitric oxide is also colorless and non-flammable, but it is very toxic. Nitrogen dioxide is likewise noxious, but with a red and brown color. It is non-flammable and odorless. Nitrous oxide comes from both human (20 %) and natural (80%) resources. In fact, all of the nitric oxide produced in the atmosphere is generated from human resources. Nitrogen dioxide and nitric oxide in any amount are considered to be air pollutants [2].

2.3. Sulphur oxides

Similarly, sulphur oxides come in a variety of types. The greatest type emitted into the atmosphere is sulphur dioxide, most commonly with a small amount of sulphur trioxide being released simultaneously. Sulphur dioxide gas is colorless and non-flammable. Sulphur trioxide gas is colorless, very over-active, and is easily condensed into a liquid. Pollution from sulphur dioxide is often created when sulphide is melted. Many useful elements exist naturally in sulphide [2].

2.4. Aerosols

Aerosols contribute to pollution. An aerosol is formed when small solid particles, generally called suspended particles, combine with liquid droplets that are dispersed in a gas. (Pure water is an exception to this classification). Fog, smoke from fire, dust, and car smoke are known as a major source of aerosol. Aerosols can be made from the decomposition of soil. Sometimes aerosols can be formed from living particles, such as bacteria, algae, mold, and spores, or from non-organic sources, such as metals, dust and sea salt. Aerosols are of particular interest because: Most aerosols, when compared to other pollutants, can cause breathing problems. Some aerosols increase the toxic effects of other pollutants. Aerosols increase atmospheric pollution and decrease visibility. Some aerosols are made from gaseous pollutants, which exist in the atmosphere [2].

2.5. Hydrocarbons

Hydrocarbons are chemicals made from the bonding of hydrogen and carbon. There are several thousand known hydrocarbons. At room temperature, hydrocarbons can be found in all three physical states, as a solid, liquid, and as a gas. The physical features are dependent on their exact molecular structure and the number of carbon atoms present. Most hydrocarbons enter the atmosphere from natural sources. Almost all of these are involved in biological processes [2].

2. 6. Bio-filtration

Using micro-organisms in the purifier when refining biological contaminants from contaminated flow is known as bio-filtration. Bio-filtration machines are used mainly for refining contaminated gases. At first, the contaminated gas stream will be wet until it enters the environmental context where it is then purified through filtration. Bio-filters treat pollutants through the use of micro-organisms. These microorganisms break down the contaminants, using the energy they gain from the by-products for proliferation and metabolic interactions. The processes that occur in a bio-filter can be explained in four main steps:

Gas with pollutants enter the liquid phase that surrounds the micro-organisms. Pollutants are decomposed by micro-organisms, which present in the bio-film. The final products of the decomposition are carbon dioxide, water, mineral salts, and bio-mass (producing more organisms). Sometimes, depending on the type of micro-organism used, carbonic acid is also produced. The final products return to the liquid phase and then into the gas phase. The bio-filter is discarded. The air is clean.

One of the main benefits of using bio-filtration over other filtering methods, such as burning or adsorption, is that the pollution is completely destroyed through bio-filtration. There is no need for recycling tools when this method is used. Bio-filtration has been used since 1960 in Europe and Asia to purify gas flow which included volatile compounds, such as benzene, toluene and styrene. The use of bio-filters is very effective, especially in cases of high-volume air flow with low concentrations of volatile organic compounds. Pollutants into the steam are slowly adsorbed into biological layer and then refined by the microorganisms. In bio-filtration, the organisms living in the bio-filter do the filtration task [4].

3. Removal of vehicle pollutants through bio-filtration technology

The main pollutants produced by diesel vehicles include nitrogen and sulphur oxides, carbon monoxide, aerosol and hydrocarbons. The removal of these materials through bio-filtration technologies will be examined [5].

3.1. Removal of nitrogen oxides and Sulphur

Bio-filters filled with soil and compost will remove nitrogen oxides. Compost bio-filters can clean 90 percent of a gas stream containing nitric oxide at a concentration of 500 ppmv. However, the yield of this system usually decreases with time depending on the type of compost used. It can decrease down to only 45 to 70 percent.

3.2. Removal of carbon monoxide

In a 24 hour period of time, a compost bio-filter can filter out 90 percent of carbon monoxide gas with a concentration of 1000 ppm. Similarly, bio-filters using micro-organism show an 80 percent efficiency. Under conditions of continuous flow, they can filter up to 45 percent of carbon monoxide produced from a gasoline engine. In order to remove carbon monoxide with maximum concentrations of 500 to 1000 ppm, bio-filters may be able to be used depending on the flow conditions. However, catalytic converters are usually used in this case, since they are more affordable.

3.3. Removal of aerosols

A multi-phase bio-filter can be used to remove particles from aerosols without any particular problems.

3.4. Removal of hydrocarbons

The first bio-filtration applications in the air purifier industry were used for the treatment of volatile organic compounds. Bio-filtration was found to be quite capable of removing hydrocarbon compounds.

4. An estimate of the concentration of pollutants from an urban bus

To estimate the concentration of pollutants from an urban bus, we use the environmental standard provided by the manufacturer (Table 1). This is a reliable source of information. We consider the normal safety factor to calculate a value that is close to the amount of pollutants generated. Most buses used inside the city limits of Tehran are one of three models of bus produced by Iran Khodro; the 0457, 0457G-OSG, or MEGATRANS.

Table 1. Models of bus produced by Iran Khodro

Environmental standards	EuroII	EuroII	EuroII
Cylinders volume (cc)	11967	11967	11967
Number of cylinders	6, linear	6, linear	6, linear
Maximum torque	1250 Nm at 1100 rpm	1080 Nm at1200 rpm	1250Nm at 1100 rpm
Engine power	299hp at 2000 rpm	300hp at 2000 rpm	299hp at 2000 rpm
Model	0M 457LA	0457G - OSG	MEGA TRANS

Because the Euro II standard units are grams per kilowatt hour, we need the engine power in order to calculate the pollution level produced when a bus is idling. To do this, we use an experimental graph and an assessment to calculate the engine power. We use the following equation to calculate:

$$P = W.T \qquad (1)$$

The engine power at 2000 rpm is equal to 299 hp.
We now have two points of the diagram. One point is derived from the calculation A (1065, 2000) and another is the maximum point B (1100, 1250). Although this diagram is for two car engines, the diagram is similar for a bus. Consider the experimental diagram below (Fig. 1) with the premise that the relationship between torque and rotational speed in the equation is parabolic [5].

Therefore:

$$F(\mathrm{w}) = \mathrm{T} = 1065\,\mathrm{N.m}$$

In the case of this project, we need to know the power of the engine in standby mode. According to observations, an idling engine in a bus worked around 500 to 700 rpm. Using an average of 600 rpm:

$$\begin{aligned} &If: \\ &\quad w = 600\ RPM,\ T = 1192.6\ N.m \\ &\qquad \rightarrow C\ (600, 1192.6) \\ &\qquad P\ (\mathrm{c}) = T.\mathrm{w} \qquad (2) \\ &\rightarrow P(\mathrm{c}) = 1192.6 \times 600 \times (2\Pi / 60) \\ &\mathrm{P(c)} = 74.89528\ kW \end{aligned}$$

Fig. 2 shows the points A, B and C.

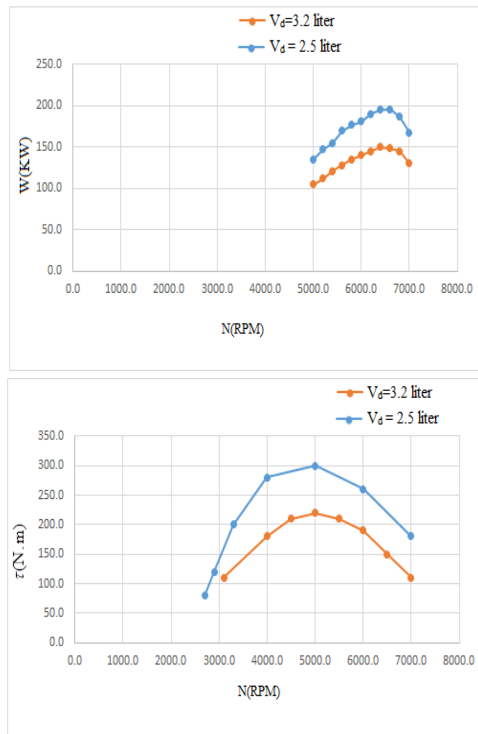

Fig. 1. Torque and power diagram of the rotational speed of two motors

To obtain bus contaminant standard concentrations, considered the time as a minute. The amount of power consumed in standby working mode is about 75kw. The amount of pollutants for a bus each minute in grams is therefore the following:

$$\begin{aligned} &CO\ :\ 4 \times 1/60 \times 75 = 5\ g \\ &NOx\ :\ 7 \times 1/60 \times 75 = 8.75\ g \\ &HC\ :\ 1.1 \times 1/60 \times 75 = 1.375\ g \\ &PM\ :\ 0.15 \times 1/3 \times 75 = 0.1875\ g \end{aligned}$$

To get pollutant concentrations using the cylinder volume, calculate the volume of output current generated from bus exhaust in one minute of time:

$$\begin{aligned} &V = 11.967\ lit \\ &N\ jdle = 660 RPM \end{aligned}$$

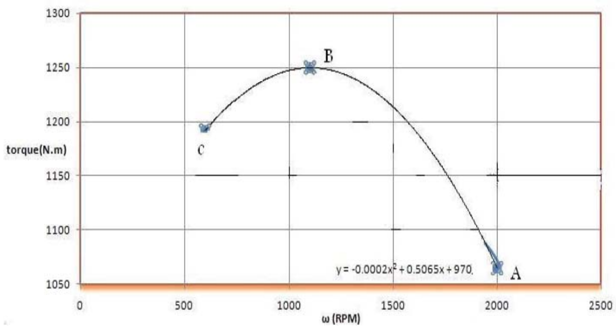

Fig.2. Diagram of torque to rotational speed for a common bus engine

Because these buses have four-stroke diesel engines, for every two rounds, the cylinder will be empty once. The total volume discharged in one minute is equal to the following:

$$11.967 \times 300 = 3590\ lit$$

We can calculate pollutant concentrations in terms of g/ms in one minute of idle time. The amount of sulphur oxides for motor vehicles that consume diesel was considerable when including all buses in city. We don't have any information on the amount of sulphur dioxide that is produced by a bus. This value can be obtained experimentally.

5. The estimated flow of polluted terminals within the city of Qazvin

To get an approximate number of buses idling in standby mode in the bus terminal, statistics have been recorded in the Tables 2 and 3. These measurements were performed between 6 and 8 a.m.
The bus output flow per minute is 3590 liters. For 161 buses in Qazvin City, this amount is 577990 liters per minute or 9.63 cubic meters per second. With using the bio-filtration system, we can calculate flow using these formulas:

$$Q = 9.63\frac{m^3}{s}$$

$$CO : \frac{5}{3.590} = 1.3927\frac{g}{m^3}$$

$$NO_x : \frac{8.75}{3.590} = 2.4373\frac{g}{m^3}$$

$$PM : \frac{0.1875}{3.590} = 5.2228 * 10^{-5}\frac{g}{m^3}$$

$$HC : \frac{1.375}{3.590} = 0.383\frac{g}{m^3}$$

The filtering system should refine the flow with these formulas:

$$Q(flow) = 2057283(\frac{m^2}{s})$$

$$CO : \frac{5}{3.590} = 1.3927(\frac{g}{m^3})$$

$$No_x : \frac{8.75}{3.590} = 2.4373(\frac{g}{m^3})$$

$$HC : \frac{1.375}{3.590} = 0.3830(\frac{g}{m^3})$$

$$PM : \frac{0.1875}{3.590} = 5.2228 \times 10^{5}$$

Table 2. Details of the bus fleet in this situation

Number of vehicles in the fleet	Line code	Line name	Row
14	4	Bazar-Kosar	1
5	1	Bazaar-Gias Abad	2
14	5	Terminal-Minoodar	3
8	8	Norooziyan-Dorahi	4
4	15	Tehran Gadim-Bazzar	5
9	22	Daneshgah Azad	6
5	14	Vali Asr-Rah Ahan	7
9	9	Terminal-Edarat	8
21	3	Chaharsad -Rah Ahan	9
9	21	Terminal- Chaharsad	10
3	11	Saadat-22 Bahman	11
5	16	Azadi-Dorahi	12
10	7	Azadi-Kosar	13
3	19	Kanal-Poonak	14
13	6	Minoodar-22 Bahman	15
4	12	Shahid Ansari-Khayam	16
8	13	Saadat-Bazzar	17
17	2	Beheshti-Edarat	18
4	12	Shahid Ansari-Khayam	19
161		Totally	
6	23	Qazvin-Egbaliye	20
14	25	Qazvin-Alvand	21
9	17	Qazvin-Bidestan	22
12	24	Qazvin-Mohammadiye	23
6	18	Qazvin-Mahmood Abad	24
47		Totally	

Table 3. Number of buses idling in standby mode in the bus terminal

Line Name	6-6:15	6:15-6:30	6:30-6:45	6:45-7	7-7:15	7:15-7:30	7:30-7:45	7:45-8
Qazvin-Mohammadiye	23	24	23	24	23	24	23	24
Beheshti-Edarat	18	18	2	18	2	18	2	18
Daneshgah Azad	22	9	22	9	22	9	22	9
Kanal-Poonak	5	19	7	19	5	19	7	19
Terminal-Chaharsad	13	14	21	14	4	21	4	21

6. Suggested plans and a comparison of bio-filtration technologies with catalytic converter

To control vehicle exhaust and transfer it to the filtration system, pollutants should be transferred to the refining system with pipes that are connected to the bus exhaust. Two different modes can be considered. In one situation, for each bus line, the ramp entrance can be fitted with a small filtration system with limited capacity equal to the number of buses in the line. Conversely, one large filtration system could be implemented for all of the regular buses with a relatively complex network of pipes. This complex system would lead pollutants to a refining system. The second method might require underground plumbing and would therefore be costly, but it would be effective. The pipes would need to be maintained throughout the entire system, as opposed to in a single location that would be required in the first mode. In the first scenario, the pipelines would be short but would cover only a limited small area. In this regard, it would be easier and less costly to check and control the status of the system. Next, we compare the raw materials and cost for a bio-filtration system versus a catalytic converter for the bus terminal's filtration system.

7. Use of raw materials

Using raw materials in a filtration system can be divided into two parts [6]:

1. Raw materials related to fabrication of the equipment used in the system
2. Raw materials used during system performance.

In this case, we are referring to the need for carbon, water, and energy.

Using carbon in bio-filters is significantly lower in cost than using a thermal oxidizer, such as natural gas to reach the reaction temperature.

Bio-filters require more water than a bio-tri-klieg filter. This is mainly due to water discharge (blow down) in a bio-filter. All biological filtration systems use a wet input gas stream. In multi-phase bio-filters if solid particles exist in inlet gas, some water will be lost during filtration. However, using water in a bio-filter increases the time needed to purify material more than the use of thermal oxidation systems. To determine which is best, we must consider the existing water in combustion products and the polluted flow. Taking these into consideration, bio-filtration systems reduce the need for water.

Thermal oxidation systems require more energy that bio-filter systems. This is usually due to the natural-gas consumption. In addition, natural-gas consumption significantly increases the cost of thermal oxidizer systems. The volume of volatile organic compounds is very large in thermal oxidizer systems, owing to the fact that they are required for ignition of the fuel. If a change in that input composition is needed when using natural gas, the cost is again driven up.

8. Cost comparison of filtering technology

Each filtering technology has its own work range and special conditions. We can't compare the cost of one technology with another without considering those different working conditions. Therefore, for surveying the cost of bio-filtration technology, we used only research results to compare against other technologies. The subsequent information refers to a sample of this research.

In 1987, some monitoring wells were drilled in California, America in order to determine the amount of solved oil hydrocarbons in soil and underground water. Then, in 1994, research related to removing volatile organic compounds from output gas in monitoring wells used different systems, including bio-filtration. In this research, an economic analysis was performed between the various technologies. The technologies used included the most common methods to remove volatile organic compounds. They included Catalytic oxidizing, thermal oxidizing, carbon adsorption, and bio-filtration.

Information regarding the costs of the various methods can be achieved through the use of experimentation with these systems and through analysis of data provided directly from the equipment vendors. The following assumptions were used for this analysis:

1. Flow of filtered gas is equal to 50 cfm.
2. The average concentration of oil hydrocarbons is equal to 200 ppm.

Pollutant gas flow is almost constant and continuous.

The repair cost for these four systems is not considered.

In earlier dug wells, the pollutant concentrations are often several thousand ppm, rendering the thermal and catalytic oxidizing methods unsuitable to remove them. The basic cost of the bio-filtration system, catalytic oxidizing, thermal oxidation and carbon adsorption were calculated respectively as $30,000, $45,000, $35,000, and $20,000. Annual cost of the carbon adsorption system in the first year was $20,000. As time goes on, a control is no longer required, reducing the cost to $15,000 per year [5].

The annual cost of bio-filtration, catalytic oxidation, and thermal oxidation were estimated at $3,000, $9,000, and $17,000 respectively. These costs are fixed over a period of three years. Figure 4 shows the total cost for each type of technology over a period of three years. The total initial cost in the three-year period for bio-filtration, oxidizing catalyst efficiency, thermal oxidizing, and carbon adsorption are thus respectively $39,000, $72,000, $86,000, and $72,500. This comparison shows that the costs for the filtration of polluted gas flow with its pollutants can be removed by bio-filtration. Taking into consideration the concentration and the flow of pollutants within the bio-filtration system as it is functioning, use of this system compared to other systems can yield considerable savings.

Another research project that was done looked at the removal of isopentane with pollutant concentrations of 1000 ppm and a removal efficiency of 95 percent using four different technologies: catalytic oxidizing, thermal oxidizing, carbon adsorption, and bio-filtration [6].

In this research, it was shown that the low-cost technology is bio-filtration. (Figure 3). Clearly given the same conditions, bio-filters are seen to have a more affordable cost.

Particulate matter emissions are highly regulated in most industrialized countries. Due to environmental concerns, most industries are required to operate some kind of dust collection system to control particulate emissions. These systems include inertial collectors (cyclone collectors), fabric filter collectors (bag houses), wet scrubbers, and electrostatic precipitators [7].

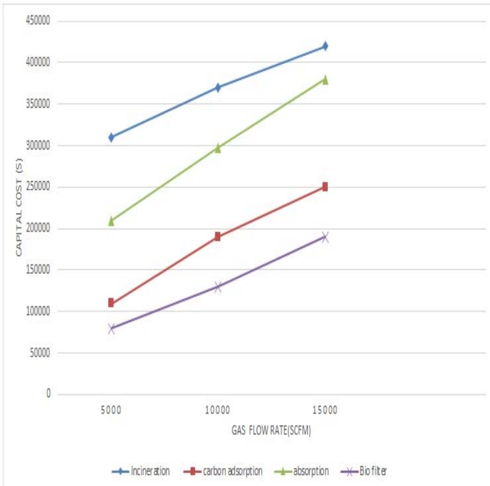

Fig.3. Comparison of the cost of four technologies for removal isopentane pollutants

Cyclone collectors are useful for removing large, coarse particles and are often employed as a first step or "pre-cleaner" to other more efficient collectors. Fabric filters or bag houses is the most commonly employed in general industry. They work by forcing dust laden air through a bag-shaped fabric filter leaving the particulate to collect on the outer surface of the bag and allowing the now clean air to pass through to either be exhausted into the atmosphere or in some cases reticulated into the facility. Common fabrics include polyester and fiber glass and common fabric coatings include PTFE (commonly known as Teflon©). The excess dust build-up is then cleaned from the bags and removed from the collector. Wet scrubbers pass the dirty air through a scrubbing solution (usually a mixture of water and other compounds) allowing the particulate to attach to the liquid molecules. Electrostatic precipitators electrically charge the dirty air as it passes through. The now charged air then passes by large electromagnetic plates, which attract the charged particle in the airstream collecting them and leaving the now clean air to be exhausted or recirculated.

9. Conclusion

Bio-filters are an important option for filtering combustion gases from diesel engines and can be effective in developing a pollution plan for bus terminals. However, microorganisms which harm a bio-filter, show different responses against the flow of gas. Different tests to remove a specific pollutant by bio-filter were examined. But the tests for the detection of normal conditions when using a bio-filter for filtration of gas flow combustion pollution, was not performed.

One of the disadvantages of using a catalytic converter at a bus terminal is one of supplies. The minimum temperature needed for of a catalytic converter to work requires a heating system which usually works with fossil fuels, such as natural gas. Such a system is costly and generates pollutants. It is suggested that use of a heating system that uses solar energy be examined as an alternative.

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