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Impact of Compressed Natural Gas in Changing the Air Quality of Agartala City with reference to CO_2 Emissions

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Transport sector is one of the very significant sources of air pollution. The environmental effects of transport are huge because transport sectors are the major users of energy, and it burns most of the world's petroleum. Within the transport sector, road transport is the largest contributor to air pollution. Carbon emissions from conventional fuels such as petrol and diesel contribute significantly to this pollution. Sustainable approach to urban transport addresses the environmental concerns with the need to provide affordable mobility choices to the rapidly growing population of urban areas. The aim is to validate Compressed Natural Gas (CNG) as a safe alternative vehicular fuel to reduce CO_2 emission in Agartala city. For that reason, an attempt to conversion of vehicles running on harmful conventional fuels into CNG fuel in the Agartala Municipal Corporation (AMC) area under three intervention scenarios has been undertaken and analyzed. The result reveals a huge change in environmental status, which makes it appropriate to conclude that the use of CNG as a vehicular fuel is the best sustainable approach in urban surface transport to significantly reduce CO_2 emission.

1. Introduction

In the transportation sector, diesel accounts for two-thirds of all fuel consumption (Aggarwal, 1999). Diesel exhaust is harmful to health due to its various substances. To address this, the transportation sector is adopting alternative fuels (Ramli et al., 2017). Compressed natural gas (CNG), which is one of these alternative fuels, can meet the demands of countries worldwide (Khan et al., 2015). CNG is introduced as a clean-burning alternative fuel for automobiles (Lejda et al., 2021) the use of CNG fuel as an alternative to conventional fuel in public and private vehicles helps by lowering air pollutants (Kaushik et al., 2019). Carbon dioxide (CO_2) emissions, as a greenhouse gas, play a pivotal role in driving climate change posing a significant global threat (Qin et al., 2023). The CO_2 emissions from CNG vehicles are lower than those from conventional vehicles because natural gas has a lower carbon intensity than petrol or diesel (Iqbal et al., 2011), CNG emits about 25% less CO_2 (Wakdikar, 2002) than diesel fuel for the same amount of energy and thus makes an important contribution to the reduction of CO_2 and pollutants (Milojević et al., 2011). Compared to diesel vehicles, CNG vehicles have a lower impact on climate change (Rose et al., 2013) as CNG brings profit of 20 to 25 % compared to gasoline and 10 to 15 % compared to diesel in emissions of Greenhouse Gas on the overall chain of use (Amrouche et al., 2012). Therefore, Compressed Natural Gas may undoubtedly be considered to be an environmentally clean alternative to these fuels (Fattah et al., 2023). At the same time, one of the major advantages of CNG is that it offers a cheap source of energy. To run with expensive fuels such as gasoline and diesel, the low-cost CNG offers a glimmer of hope (Khan et al., 2016). Compressed natural gas (CNG) has been considered one of the finest alternatives to fossil fuels due to its global availability, inherent capacity to burn cleanly, affordability as a fuel, and adaptability with both petrol and diesel engines (Shamsapour et al., 2021). Therefore, to balance the supply and demand of energy and to limit the overall release of greenhouse gases, an appropriate energy policy must be implemented for the transportation sector. The major objective of the study is to assess the environmental impacts of the use of CNG as a vehicular fuel. It reveals current emission levels of CO_2 in the Business As Usual (BAU) scenario and the impact it has on the environment by converting all the liquid fuel-based vehicle engines into the natural gas-

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based engine, which may be referred to as an environment-friendly fuel, in the city. The results show that the replacement of CNG fuel with high-emission fuels can have a significant effect on reducing CO_2 emissions.

2. Study Area

Agartala is the capital of Tripura and is an important city in the North-East India. Agartala is situated in West Tripura District. AMC area has a total population of 4,00,004 (Census 2011) with a total area of 76.5 km^2 (City Development Plan, Agartala, 2006). Agartala city is the main hub of business, government, industry, education, and health services in Tripura. There are transport systems that connect the city via rail, air, and road. For the present study 31 road traffic intersections connecting almost all the major roads, have been considered all over the municipality which accounts for a significant amount of CO_2 and other greenhouse gas emissions because of its heavy traffic flow.

3. Methods and Methodology

This research work is largely dependent on primary data which has been collected from 31 intersections for fulfilling the objectives of the study. The data that has been collected from the intersection were the number of CNG and non-CNG vehicles running on the roads during peak hours.

The emission rate of per kg CO_2 emitted per kg/litre of the vehicular fuel used

An emissions factor is a measure of the amount of a pollutant that is released into the atmosphere because of a particular activity (Agyemang-Bonsu et al., 2010). The emission factor for vehicles depends on various factors such as fuel type, vehicle type, vehicle age, engine type, etc. There is limited availability of age-wise data for various vehicle categories running on diesel, gasoline, and CNG at the city level. Therefore, for this study, the CO_2 emission factor of vehicles using different types of fuel has been taken into account. Using the emission values of these fuels and the number of vehicles running on these fuels, 3 different intervention scenarios have been performed to assess the CO_2 emissions of the use of CNG as a vehicular fuel.

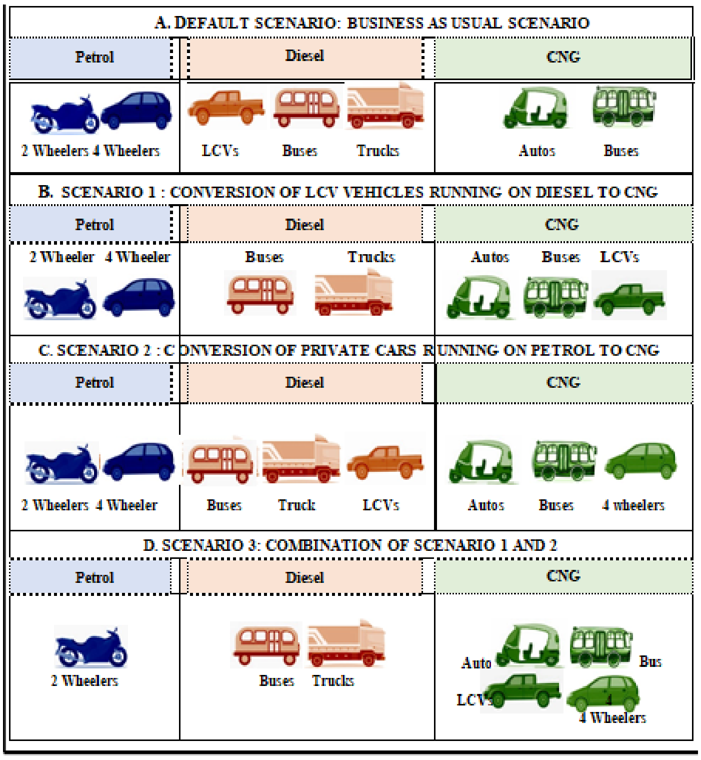

Figure 1: The schematic illustration of the three intervention scenarios

Figure 1 shows the different what-if intervention scenarios (conversion of non-CNG vehicles into CNG vehicles) explored in the current study. The default scenario shows the Business As Usual (BAU) scenario. It comprises the present usage of fuel for different categories of vehicles. Two-wheelers and cars use petrol; diesel is used by LCVs, buses, and trucks whereas auto rickshaws and buses in Agartala operate on CNG.

Emission levels of different fuel-used vehicles in each traffic intersection were calculated through equations 1, 2, and 3.

$$EL^P = \sum N^P_{(i+j)} \times EF_C^P \quad (1)$$

$$EL^D = \sum N^D_{(k+l)} \times EF_C^D \quad (2)$$

$$EL^{NG} = \sum N^{NG}_{(m+n)} \times EF_C^{NG} \quad (3)$$

Where, N is the number of vehicles, P, D, and NG are fuel types petrol, diesel, and CNG, vehicle types bike (i), car (j), LCV (k), bus (l), truck (m), and auto rickshaw (n) denotes respectively, EF_C is the emission factor.

The following equation (4) has been utilized to calculate the total emission of carbon

$$TE_C = EL^P + EL^D + EL^{NG} \quad (4)$$

Scenario I

In this scenario conversion of possible diesel vehicles has been considered. Conversion of buses and trucks running on diesel is not feasible as their engine and make need to be changed completely. However, LCVs are considered in this category to be converted into CNG. Next to, calculate the reduced carbon emission of each intersection the following formula has been used.

$$REL_{CScI} = ELN_k^{D} - ELN_k^{NG} \quad (5)$$

Where, REL_{CScI} is the reduced level of carbon in scenario I, EL is the emission level of N number of vehicles, D, NG denotes fuel types and k is the vehicle types.

Scenario II

In scenario II the conversion of possible petrol vehicles, i.e. private cars to CNG vehicles has been considered. Conversion of 2-wheelers into CNG is not possible as 2-wheelers cannot accommodate the cylinder required for the CNG fuel. Though cars are running on CNG in the city there are considerable numbers of cars running on petrol hence based on an assumption that all the cars are operating on petrol this scenario has been made workable. In scenario II using the equation to calculate the reduced level of carbon emissions are

$$REL_{CScII} = ELN_j^{P} - ELN_j^{NG} \quad (6)$$

Here, REL_{CScII} is the reduced level of carbon in scenario II, EL is the emission level of N number of vehicles, P, NG denotes fuel types and j is the vehicle types.

Scenario III

Scenario III is the combination of both the above-mentioned scenarios. Diesel-run LCVs and petrol-run four-wheelers are considered in this category to be converted into CNG. The primary motive behind the performance of these scenarios is to determine the change in the level of CO_2 emission in each of the successive scenarios and at last how much total pollution can be reduced when it reaches the last scenario.
Equation 7 was utilized to estimate the reduced level of carbon emission in each of the selected nodes of the study area.

$$REL_{CScIII} = REL_{CScI} + REL_{CScII} \quad (7)$$

The emission rate after conversion has been calculated through equation 8.

$$ER = TE_C BAU - TE_C Scenario\ III \quad (8)$$

Here, ER is the emission rate after the conversion of petrol and diesel vehicles to CNG, TE_CBAU is the total emission of carbon in the business-as-usual scenario and TE_CScenario III is the total emission of carbon in scenario III.

4. Results and Discussion

4.1. Emission level after conversion of petrol and diesel-powered vehicles to CNG powered vehicle

The present scenario of the usage of the fuels for the vehicles in the city of Agartala has been studied and the rate of emission from vehicles running on each fuel type, i.e. diesel, petrol, and CNG respectively has been calculated. In addition, three "what-if" intervention scenarios were taken into account to determine the extent of improvement of air quality due to the reduction in the primary emission of air pollutants.

Table 1 : Emission factor of the CO_2 kg/ kilometres (km) of the fuel

Fuel	Emission (Kg/kilometres)
Petrol	0.22
Diesel	0.21
CNG	0.163

Source: Iqbal et al, (2011), Verma and De (2001)

Table 2: Level of CO_2 in different scenarios for all the intersections in Agartala

Intersection	TEc			
	BAU	Scenario I	Scenario II	Scenario III
Nagerjala	556.77	550.801	536.934	530.965
Battala	566.03	559.685	548.873	542.528
Amtali Bypass	419.758	413.977	409.726	403.945
Hapania	369.545	365.503	357.689	353.647
ONGC	395.776	391.264	384.49	379.978
Badharghat	391.514	387.66	379.202	375.348
Drop Gate	477.956	473.679	461.654	456.717
Camper Bazar	216.785	214.388	209.888	207.491
Fire Service Chowmuhani	501.277	496.718	483.493	478.934
Ker Chowmuhani	440.291	437.894	425.072	422.675
Durga Chowmuhani	433.97	431.056	421.715	418.801
Paradise Chowmuhani	502.147	499.703	484.078	481.634
Kaman Chowmuhani	494.19	491.041	476.691	473.542
IGM Crossing	429.9	427.503	417.531	415.134
Orient Chowmuhani	432.366	429.499	417.033	414.166
Bidurkarta Chowmuhani	362.619	359.893	349.566	346.84
Rajbari	462.352	459.955	447.589	445.192
Ganaraj Chowmuhani	411.427	409.171	397.69	395.434
Colonel Chowmuhani	459.049	456.323	444.628	441.902
North Gate	453.092	449.896	438.386	435.19
Bhagaban Thakur	393.348	390.575	381.036	378.263
Math Chowmuhani	419.622	417.319	405.6	403.297
Khayerpur	253.073	250.441	243.782	241.15
Gurkhabasti	500.285	497.089	480.221	477.025
Secretariate House	451.867	448.718	435.679	432.53
Albert Ekka	453.053	448.87	437.036	432.853
Usha Bazar	264.611	262.073	253.325	250.787
Narsinghar	251.446	249.002	240.217	237.773
GB Bazar	469.794	467.115	456.285	453.606
Nandan Nagar	253.471	251.027	242.869	240.425
Jogendra Nagar	263.452	260.726	253.078	250.352

Source: Calculated by the authors based on primary data and emission factor

Through this detailed study, it has been possible to identify which of these intersections are in a more vulnerable state and which one is comparatively having a low presence of CO_2. The result of the performed calculation shows that the emission level is reduced at all of the intersections because of the conversion which will undoubtedly ensure environmental security by reducing the vehicular pollution of the city. This will benefit the people of Agartala to breathe clean and will keep the people free of many diseases as well which is associated with the inhaling of unclean air.

Table 2 depicts that, among all the intersections, Nagerjala has the highest CO_2 emission (556.77kg/km) in the Business As Usual scenario because it is the busiest terminal; and supports all the inter-city bus services which usually run on diesel as well as other vehicles like private cars and bikes which run on petrol. This intersection has been depicted to reduce the highest CO_2 emission (25.805 kg/km) after the possible conversion of vehicles. Battala intersection, which is the busiest intersection and has a significant commercial area around which greatly increased traffic volume and vehicular emission has reflected a reduction of 23.502 kg of CO_2. Gurkhabasti which is home to several government offices experiences the large number of vehicles running on harmful fuels in this area. After conversion, this intersection has reduced CO_2 (23.26 kg) after Nagerjala and Battala. It is noteworthy to emphasize that due to the inherent risk, ministers' automobiles and ambulances are not equipped with compressed natural gas (CNG). After converting possible petrol cars and diesel-running LCVs to CNG, 532.712 kg/km CO_2 emission has been reduced for the whole of Agartala city. Camper Bazar has the lowest CO_2 presence which is 216.785 kg mainly because this is a minor intersection with fewer vehicles plying through it and after conversion of fuel the emission at this intersection will be reduced by 9.294 kg/km. Contrarily at major intersections, the difference in reduction is lesser between the BAU scenario and scenario III as because large number of auto-rickshaws, which are already operating in CNG and E-rickshaws ply through these intersections.

Table 3: The difference in the emission rate of CO_2 in the whole of Agartala by the conversion

Intersection	Emission in Business As Usual Scenario	Emission After Conversion	Reduced CO_2
Nagerjala	556.77	530.965	25.805
Battala	566.03	542.528	23.502
Amtali Bypass	419.758	403.945	15.813
Hapania	369.545	353.647	15.898
ONGC	395.776	379.978	15.798
Badharghat	391.514	375.348	16.166
Drop Gate	477.956	456.717	21.239
Camper Bazar	216.785	207.491	9.294
Fire Service Chowmuhani	501.277	478.934	22.343
Ker Chowmuhani	440.291	422.675	17.616
Durga Chowmuhani	433.97	418.801	15.169
Paradise Chowmuhani	502.147	481.634	20.513
Kaman Chowmuhani	494.19	473.542	20.648
IGM Crossing	429.9	415.134	14.766
Orient Chowmuhani	432.366	414.166	18.2
Bidurkarta Chowmuhani	362.619	346.84	15.779
Rajbari	462.352	445.192	17.16
Ganaraj Chowmuhani	411.427	395.434	15.993
Colonel Chowmuhani	459.049	441.902	17.147
North Gate	453.092	435.19	17.902
Bhagaban Thakur	393.348	378.263	15.085
Math Chowmuhani	419.622	403.297	16.325
Khayerpur	253.073	241.15	11.923
Gurkhabasti	500.285	477.025	23.26
Secretariate House	451.867	432.53	19.337
Albert Ekka	453.053	432.853	20.2
Usha Bazar	264.611	250.787	13.824
Narsinghar	251.446	237.773	13.673
GB Bazar	469.794	453.606	16.188
Nandan Nagar	253.471	240.425	13.046
Jogendra Nagar	263.452	250.352	13.1
Total	12750.84	12218.12	532.712

Source: Calculated by the authors based on Primary data

When looked at from a macro level, in the whole of Agartala, CO_2 emitted by the vehicles is calculated and be 12750.84 kg/km. After the conversion of possible diesel vehicles, i.e., LCVs, the emissions were reduced to 12648.56 kg/km (reduced by 102.272 kg/km). If the feasible petrol vehicles are converted into CNG, from the present scenario, the emission is reduced to 12321.06 kg/km (reduced by 429.78 kg/km). With the combination of both of these scenarios, the total emission of CO_2 will reduce to 12218.12 kg which is 532.712 kg less than the original state. However, it should be mentioned that buses for intra-city travel are not popular in a medium-sized city like Agartala, and whatever few routes in intercity travel traverse through the city run on CNG. Another aspect is that LCVs running in the city cannot be directly converted to CNG, its make need to be rebuilt before the conversion.

5. Conclusion

The most effective way to reduce the amount of CO_2 is to burn less liquid fuels and replace them with CNG fuel. Due to its numerous benefits, the Indian government has targeted to replace all conventional fuel vehicles with CNG vehicles. With the implementation of CNG as an alternative to diesel or petrol-fuelled vehicles, the concentration of CO_2 in the city significantly decreased. With the combination of both of the scenarios performed in this paper, the total emission of CO_2 will reduce to 12218.12 Kg/km from 12750.84 Kg/km, which is 532.712 kg less than the present scenario. Since Agartala is a comparatively small municipal corporation with vehicular movement much less than many other major cities, vehicular emission is within satisfactory standards in most of the intersections. The vehicular numbers will be increasing with the growth of the city and so will its vehicular pollution levels. Agartala is the city, that used CNG on vehicles in a big way in North East India. However, the significance of the study lies in the fact that Agartala has the potential to keep these standards within the limit to convert possible petrol and diesel-running vehicles to CNG vehicles.

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