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Estimation of effect of gasoline quality improvement on reduction of air toxic emissions in Dhaka

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Gasoline quality improvement alone can reduce total pollution load from vehicles to a considerable extent. A spreadsheet-based model has been developed in the present study to demonstrate this. An annual emission inventory for gasoline-driven vehicles was prepared with respect to volatile organic compounds, toxic air pollutants and nitrogen oxides using vehicle population data, growth rate of vehicles and usage characteristics in Dhaka. Results of the present and projected air toxic emission inventory using planned improvement in gasoline quality reveal that an emission reduction of about 20% may be achieved. A significant reduction of about 60% in pollutants like benzene justifies gasoline quality improvement in a developing country like Bangladesh.

Keywords: Exhaust volatile organic compounds, gasoline quality, polycyclic organic matter, toxic air pollutants.

MAJOR studies on automotive fuel and its impact on air quality include European Programme on Emissions, Fuel and Engine Technologies (EPEFE), Air Quality Improvement Research Program (AQIRP) of USA (also known as auto-oil) and Japan's Clean Air Programme (JCAP). The general conclusions drawn from these studies are that effects on emissions, of fuel quality changes alone, are not as significant as changes in engine technology. However, fuel quality and vehicle technologies are linked intimately and have a combined effect on emission levels[1]. This is evident from experiences of various countries that have phased out lead in gasoline and introduction of catalytic converters for reducing exhaust emissions. To phase out lead, while maintaining the octane number, there is a requirement to increase aromatics or to use oxygenates or for further severe refining. Increase in aromatics in gasoline typically results in increased benzene emissions from automotive exhaust. The key components of gasoline having an impact on air quality are lead content, sulphur content, Reid vapour pressure and benzene content. The total toxic emission from a vehicle largely depends on gasoline quality.

In Bangladesh all vehicles are imported, and there is little control over changes in engine or vehicle technology. A solution could be alternative sources of vehicles with improved technology. However, this becomes difficult as most of imported passenger cars are used vehicles. Therefore, improvement in air quality may be achieved by improving fuel quality. In view of these considerations, strategies for improvement of gasoline quality in Bangladesh, particularly in the city of Dhaka as a case study, are discussed in this communication. The effect of gasoline quality on total emission load of air toxics has been estimated by a fuel quality model. Gasoline quality parameters for the future have been suggested using the guidelines from the World Wide Fuel Charter (WWFC).

There have been various modelling studies for the estimation of pollution load from vehicles[2–4]. These studies estimated carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_x) and particulate matter (PM) emission loads. Very few of the earlier studies have estimated pollution load for air toxics such as volatile organic compounds (VOCs). The US Environmental Protection Agency (USEPA) has developed a model to calculate emissions of VOCs, toxic air pollutants (TAP), and NO_x from

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motor gasoline, known as the Complex Model[5]. Five pollutants are covered in the TAP category: benzene, 1,3-butadiene, polycyclic organic matter, formaldehyde and acetaldehyde. The Complex Model developed by EPA quantifies not only the effects of oxygen, benzene, aromatics, and Reid vapour pressure (RVP) on emissions, but also olefins, sulphur, and the per cent of fuel evapourated at 200°F and 300°F (E200 and E300 respectively). The RVP is a parameter which defines volatility of gasoline; higher the RVP, there is the possibility of vapour lock formation. RVP may be defined as absolute vapour pressure exerted by a liquid (particularly petroleum products in this case) at 37.8°C (100°F). The model estimates the effect of gasoline reformulation on vehicle emission rate[6]. The gasoline parametres and emission variables used in the Complex Model are detailed in Table 1. VOC emission reduction is primarily achieved by lowering RVP. NO_x control is achieved by control of sulphur and a possible control mechanism with aromatics[7]. TAP control may be achieved by reduction in benzene or total aromatics.

A spreadsheet based model, Air Toxic Emission Inventory (ATEI), to estimate VOC, TAP and NO_x emissions from various fuel qualities, has been developed earlier[8]. The Complex Model has been used for generating emission rates to be used in the ATEI model. A schematic diagram of the ATEI model is depicted in Figure 1. The Complex Model generates data in terms of emissions per unit distance travelled by vehicles. The cumulative vehicle-kilometres travelled in a year has been calculated using vehicle registration data and daily average distance travelled by each type of vehicle. The number of usual activity days in a year has been considered as 300 for the purpose of annual load calculation.

$$V_d = 300 * \sum N_i * D_i,$$

where V_d is the vehicle-kilometre travelled by all gasoline-driven vehicles in a year, N_i is the number in vehicles in category i and D_i is the average distance travelled per day by a vehicle in category i. The category i of vehicles considered are passenger cars, taxis, three-wheelers (baby taxis), motorcycles and other petrol-driven vehicles. The number of vehicles for 1997 and 2000 is depicted in Table 2 along with average vehicle-kilometres travelled (distance covered by each type of vehicle). The pollutant load thus calculated is

$$L_j = V_d * E_j * 10^{-9},$$

where L_j is the annual load of pollutant j in tons and E_j the emission factor derived from the Complex Model for pollutant j in mg/km. The types of pollutants j considered are VOC, NO_x, benzene, formaldehyde, acetaldehyde, poly-organic matter, 1-3 butadiene. The total air toxic emission load per annum from gasoline driven vehicles is

$$L_T = \sum L_j.$$

Emissions for future 10 years are projected using prevailing vehicle population and growth rate for each type of vehicle.

The major parametres to control gasoline quality considered in this study were lead, sulphur and benzene content. Since, in Bangladesh, lead has been removed from gasoline, emphasis was placed on sulphur and benzene. When benzene content was varied from 5% to 1% by volume of gasoline, the effect on total toxic emissions from

Table 1. Complex model variables and their relation

	Emissions							
Gasoline quality parameter	VOC	NO_x	Exhaust benzene	Non-exhaust benzene	Formaldehyde	Acetaldehyde	Polycyclic organic matter	1,3-butadiene
Benzene			♦	♦				
MTBE				♦	♦	♦		
ETBE						♦		
Ethanol						♦		
Total oxygen	✶	♦	✶				✶	✶
RVP	♦	♦		♦		♦	♦	
Total aromatics	♦	♦	♦		♦	♦	♦	♦
Sulphur	♦	♦	♦			♦	♦	♦
Olefins	♦	♦			♦		♦	♦
E200	♦	♦	♦				♦	♦
E300	♦	♦	♦		♦	♦	♦	♦

♦, Decrease in value of parameter of gasoline specification will result in corresponding decrease in emissions indicated. Similarly, increase in value of parameter will result in increase in emissions.

✶, Increase in value of parameter of gasoline specification will result in corresponding decrease in emissions indicated. Similarly, decrease in value of parameter will result in increase in emissions.

MTBE, Methyle tert-butyl ether. ETBE, Ethyle tert-butyl ether.

Table 2. Vehicle population in Dhaka and calculation of vehicle-kilometres travelled for years 1997 and 2000

Vehicle	Vehicle usage (km/yr)	No. of vehicles (1997)	Total vehicle-kilometres travelled (1997)	No. of vehicles (2000)	Total vehicle-kilometres travelled (2000)
Passenger cars	19,200	45,243	868,665,600	59,214	1,136,908,800
Taxis	30,000	–	–	800	24,000,000
Three-wheelers (baby taxis)	30,000	62,803	1,884,090,000	66,360	1,990,800,000
Motorcycles	10,000	105,673	1,056,730,000	121,156	1,211,560,000
Other petrol vehicles	20,000	Nil	Nil	2,382	47,640,000
All petrol vehicles		253,448	3,809,485,600	299,043	4,363,268,800

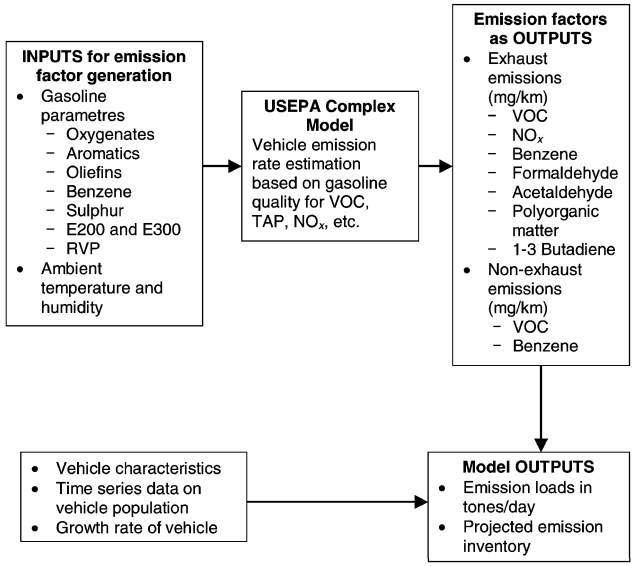

Figure 1. Schematic of Air Toxic Emission Inventory Model.

exhaust was not more than about 6%. However, reduction of nearly 60% in benzene emissions from vehicles is achievable with this reduction of benzene content in fuel.

The variation in sulphur content of gasoline was studied from 500 to 50 ppm. Reduction of sulphur to 50 ppm may be overly ambitious, but certainly it should be reduced to 150 ppm. About 13% reduction may be achieved in both total toxics and NO_x by reducing sulphur to 50 ppm. Reduction of sulphur from the present target of 250 ppm to a new target of 150 ppm may bring reduction in total toxics and NO_x by 3.4% and 3.8% respectively.

In the absence of any long-term fuel quality standards at regional level and for Bangladesh in particular, the fuel qualities suggested in the WWFC, could be a good guideline to plan for future fuel quality standards. The WWFC has been delineated with the objective of harmonization of global fuels so as to develop common, world-wide recommendations for 'quality fuels', taking into consideration customer requirements and vehicle emission technologies, which will in turn benefit end-users and all other affected parties. Four different categories of fuel quality have been established for both unleaded gasoline and diesel fuel. These are described below:

Category 1: Markets with no or minimal requirements for emission control; based primarily on fundamental vehicle/engine performance concerns.

Category 2: Markets with stringent requirements for emission control or other market demands. For example, markets requiring US Tier 0 or Tier 1, EURO 1 and 2, or equivalent emission standards.

Category 3: Markets with advanced requirements for emission control or other market demands. For example, markets requiring US California LEV (low emission vehicles), ULEV (ultra low emission vehicle), and EURO 3 and 4, or equivalent emission standards.

Category 4: Markets with further advanced requirements for emission control, to enable sophisticated NO_x and particulate matter after-treatment technologies.

The various parametres controlling gasoline quality were varied in the Complex Model according to WWFC categories 1 to 4. A comparison was made with the present typical composition of gasoline. Table 3 gives the parametres for various fuel qualities of the WWFC and the present fuel. Estimates of emission are based on the vehicle population and estimated vehicle kilometres travelled per annum (Table 3). Annual emissions as a result of variations in fuels in terms of TAP, VOC and NO_x are depicted in Figure 2.

It is clear from Figure 2 that the present fuel quality in Bangladesh is good compared to the WWFC category 1, except for emission of non-exhaust VOC and non-exhaust benzene. This control may be achieved by reducing vapour pressure. It is observed that while improving the fuel quality as suggested by the WWFC, there is a possibility of increase in formaldehyde. The gasoline quality improvement will definitely have a considerable effect on total emissions from gasoline-driven vehicles in Bangladesh.

The projected emission till year 2010 was estimated for improvement in gasoline quality in 2004 and 2006 (Table 4). These quality parametres are based on the recommendations of the Asian Development Bank (ADB) report for urban transport and environment improvement in Bangladesh[9]. Emission reduction in total pollution load with significant emission reduction for benzene is envisaged from the projected emission inventory. Reduction in sulphur has an effect on VOC, benzene, acetaldehyde, 1,3-butadiene, polycyclic organic matter and NO_x. The reduction in

Table 3. Fuel qualities used for comparison

Gasoline quality parameter	Gasoline type					
	Complex model baseline fuel	Typical present fuel in Bangladesh	WWFC CAT 1	WWFC CAT 2	WWFC CAT 3	WWFC CAT 4
Oxygenate (wt% oxygen)	0	0	0	2.7	2.7	2.7
Sulphur (ppm)	339	250	1000	200	30	0
RVP (psi)	8.7	10	8.7	8.7	8.7	8.7
E200 (%)	41	38.2	35.2	44	44	44
E300 (%)	83	88.4	73.2	79.1	79.1	79.1
Aromatics (vol%)	32	35	50	40	35	35
Oleffins (vol%)	9.2	30	30	20	10	10
Benzene (vol%)	1.53	5	5	2.5	1	1

Table 4. Projected improvement in gasoline quality

Fuel property	Prevailing quality fuel	Quality A by the year 2006	Quality B by the year 2010
Ethanol (wt% oxygen)	0	2.7	2.7
Sulphur (ppm)	250	150	50
RVP (psi)	10	8.7	5
E200 (%)	38.2	44	44
E300 (%)	88.4	80	80
Aromatics (vol%)	35	35	35
Olefins (vol%)	30	20	10
Benzene (vol%)	5	2	1

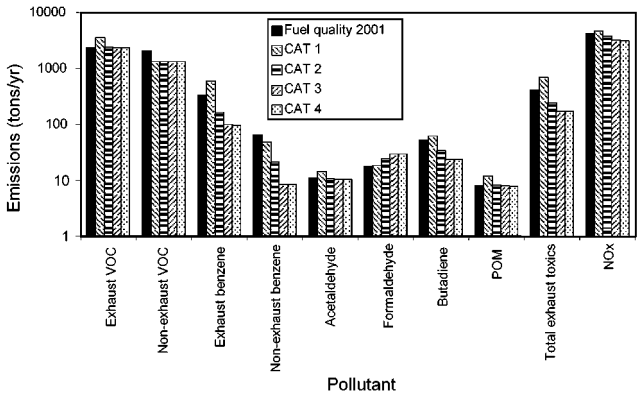

Figure 2. Annual toxic emissions: Comparison of present fuel with respect to World Wide Fuel Charter categories.

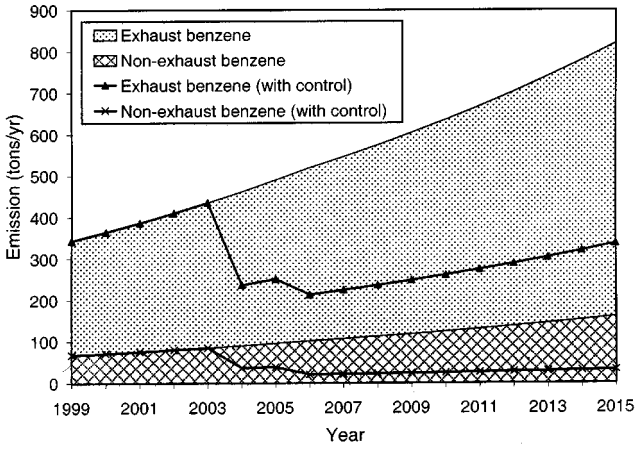

Figure 3. Projected benzene emission load for Dhaka.

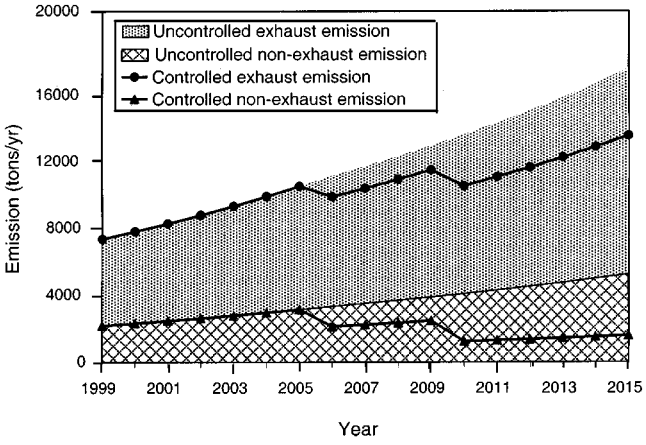

Figure 4. Comparison of emission for uncontrolled and controlled fuel quality.

these emissions is in the range 1–9% by the year 2010 after reducing sulphur to 50 ppm, whereas the total pollution load may be reduced by about 20% with the proposed improvement in gasoline quality. Figures 3 and 4 show comparison of emissions with and without fuel modifications for benzene and total toxics respectively. The emission reduction may be obtained for both exhaust and non-exhaust emissions, considering the present growth rate of vehicle population in Dhaka.

Gasoline quality improvement may have direct emission reduction benefits in case of countries like Bangladesh where all vehicles used are imported, with little possibility of technological modification. The overall toxic emission reduction achievable by modifying fuel quality will be

about 20% by the year 2010, whereas emission of carcinogenic compounds like benzene may be reduced by about 60%, This itself would be a considerable emission reduction benefit and justifies the need of fuel quality improvement. In addition, gasoline quality improvement may result in reduction of pollutants like 1,3-butadiene. Although the model developed in this study is based on emission factors estimated using fuel quality model without reference to engine technology, estimates for reduction in toxic emissions from vehicles provide a good sensitivity analysis.

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Genetic diversity analysis in traditional lowland rice (*Oryza sativa* L.) of Assam using RAPD and ISSR markers

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Genetic variability among 24 rice genotypes from Assam was assessed employing random amplified polymorphic DNA (RAPD) and inter-simple sequence repeat polymerase chain reaction (ISSR–PCR) using ten primers in each case. A total of 81 RAPD and 201 ISSR markers were generated with 92.5 and 98% polymorphism respectively. The average polymorphism information content (PIC) for RAPD was 0.741 and for ISSR markers it was 0.888. The Jaccard's similarity coefficient based on RAPD and ISSR analysis was 0.480 and 0.257 respectively. Cluster analysis and cophenetic correlation value based on the ISSR data discretely separated the accessions, according to farmer's classification. This communication reports genetic variability in rice from Assam using two molecular markers.

Keywords: Assam rice, genetic diversity, molecular markers, polymorphism information content.

NORTHEAST India has been the heartland of rice cultivation since long. Therefore, the indigenous rice germplasm of Northeast India, including Assam (known as 'Assam rice collection') is enriched with wide genetic diversity and valuable gene system for yield attributes and adaptibility[1–3]. Presently these cultivars are facing threat from the high-yielding varieties (HYVs). Hence, their conservation and characterization is important.

Some traditional rice cultivars are being maintained in the Assam Agricultural University (AAU), Jorhat and elsewhere, but they are neither exhaustive nor sufficient to represent fully the genetic diversity of the region. There is also possibility of redundant or duplicate accessions. Hence their identification, conservation and classification are needed for utilization in breeding. Because of the limitations of morphological and biochemical markers, efforts are being directed to use molecular markers for characterizing germplasm diversity[4]. Marker systems, including multiple arbitrary amplicon profiling (MAAP) approaches have been developed, such as random amplified polymorphic DNA (RAPD)[5,6], which have proven valuable in rice genetic diversity studies[7–10]. Another popular marker system, called Inter Simple Sequence Repeats (ISSRs), encompasses the broad taxonomic application of RAPD with the advantage of assessing variation in the number of SSR (microsatellite) loci[11–15]. ISSRs are semi-arbitrary markers amplified with one primer complementary to a target microsatellite. Genetic diversity among 24 indigenous rice cultivars from various localities of Assam was determined by RAPD and ISSR–PCR and the efficiency of the two markers was compared.

Details of the 24 traditional lowland rice genotypes used are given in Table 1. Seeds were collected from the Regional Agricultural Research Station (RARS), AAU. The sample includes the non-glutinous fraction[16] that belongs to isozyme groups I, II and V. DNA was extracted following the protocol of Plaschke *et al.*[17], with some modification. DNA was obtained from ten-pooled individuals per accession to ensure better representation[8]. DNA quality was checked by electrophoresis in 1× TAE buffer. Quantification and purity analysis was done using UV–VIS spec-

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