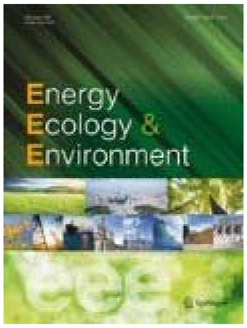

Evaporative quality of Nigeria's gasoline: truck loading perspective.

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Abstract

Gasoline emits volatile organic compounds (VOCs) that contribute to ground-level ozone formation with adverse health effects. Gasoline evaporation also results in economic losses. Hence, there is a need to understand the extent of avoidable economic losses and environmental damage. Furthermore, it becomes pertinent to investigate effective channels for reducing the emission of VOCs by preventing leakage during trucking and improving the regulation of gasoline evaporative quality (such as vapour pressure). This study focused on emissions during the truck loading of gasoline at petroleum depots in Nigeria. Gasoline evaporative emissions depend on ambient temperature, gasoline volatility, control of leakage and recovery systems. This study determined the VOC emission factor and the equivalent gasoline losses under different conditions. The results from the analyses showed that the higher the evaporative quality of the gasoline, the greater the VOCs emitted into the environment—with adverse health implications. Specifically, as much as 8510 tonnes of VOCs are issued annually from the truck loading of gasoline in Nigeria. Consequently, the country loses approximately 0.058% of total truck-out gasoline to evaporation and leakages during truck loading alone. This study provides evidence that a reduction in vapour quality with efficient recovery and control regulations would reduce VOC emissions and equivalent gasoline loss by 97.67%.

Availability of data and material

Data used for this work are easily accessible and readily available.

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Ethics declarations

Conflict of interest

The authors declare that there is no conflict of interest.

Code availability

Not applicable.

Appendix

Appendix

The following equation was used to estimate the VOC emissions from the loading of gasoline at petroleum depots in Nigeria:

$$L_{\text{L}} = 12.46 \left({\frac{SPM}{T}} \right) \times \left({1 - \frac{\text{eff}}{100}} \right) \tag{1}$$

where

- L_L loading loss or VOCs emitted during loading, pounds/1000 gallons (lb/10^3 gal) of liquid loaded.
- S saturation factor (dimensionless).

The saturation factor accounts for the variations observed in the emission rates from the different unloading and loading methods. This factor depends on the mode of operation, whether by being submerged or by splash loading. Section 5.2 of AP-42 provides suggested saturation factors for the various loading operations. Therefore, based on the investigation of the operation carried out at different loading terminals/depot, $S = 1.00$ was used for the estimation.

- P true vapour pressure of liquid loaded, pounds/square inch absolute (psia).

P was calculated using Eq. 2, obtained from regression analysis carried out by USEPA.

- M molecular weight of vapours, pounds/pound-mole (lb/lb-mole).

According to Table 7.1-2 of AP-42, the molecular weight of gasoline varies. However, Rudd and Hill (2001) showed that the molecular weight as a function of RVP could be easily fitted to a simple quadratic equation in Eq. 3.

- T temperature of bulk liquid loaded, °R—calculated using Eq. 4.
- *eff* Emission reduction efficiency. The emission reduction efficiency should account for the control efficiency and the downtime of the control device. During loading, there is an emission control system that captures and re-channels the vapour generated to minimize release into the environment. Therefore, the efficiency of emission control was investigated through inspection and interviews.

$$P = \exp \left\{ {\left[{0.7553 - \left({\frac{413}{T + 459.6}} \right)} \right] s^{0.5} \log_{10} \left({\text{RVP}} \right) - \left[{1.854 - \left({\frac{1,042}{T + 459.6}} \right)} \right] s^{0.5} + \left[{\left({\frac{2,416}{T + 459.5}} \right) - 2.013} \right] \log_{10} \left({\text{RVP}} \right) - \left({\frac{8742}{T + 459.6}} \right) + 15.64 } \right\} \quad (2)$$

where P true vapour pressure of the liquid loaded, pounds/square inch absolute (psia). T temperature of bulk liquid loaded, °F calculated using Eq. 5. s slope of the ASTM distillation curve at 10% evaporated, in degree Fahrenheit percent $s = [(°F \text{ at } 15\%) - (°F \text{ at } 5\%)]/(10\%)$.

However, in the absence of distillation data, 3.0 was used for s [as per Figure 7.1-14a of AP-42 (US EPA 2016)].

RVP = Reid vapour pressure, psi.

$$M_{\text{W}} = \left({ - 0.0023\, {\text{RVP}}^{2} } \right) + \left({0.1758\, {\text{RVP}}} \right) + 64.942 \quad (3)$$

where M_w = molecular weight of vapours, pounds/pound-mole (lb/lb-mole). RVP = Reid vapour pressure, psi.

$$T = T_{\text{AA}} + 0.003\alpha I$$ (4)

where T liquid bulk temperature, °R; T_{AA} = average daily ambient temperature, °R, which is calculated from Eq. 5; α tank shell-surface solar absorptance, dimensionless. Based on Section 7 of AP-42, a white shell with paint in average condition was assumed to represent the typical tank surface, with a reflective state of 0.25; I average daily total insolation factor in Nigeria, Btu/(ft2 day).

In Nigeria, solar radiation ranges from 3.5 kW/m^2/day in coastal zones to 7.0 kWh/m^2/day in the north, and the mean daily solar radiation is reported to be 5.25 kWh/m^2/day (1664.24 Btu/ft2/day) (Abam et al. 2014).

$$T \left({^\circ {\text{R}}} \right) = T \left({^\circ {\text{F}}} \right) + 459.67$$ (5)

where T (°R) = temperature in °R, T (°F) = temperature in °F = (T (°C) × 9/5) + 32 and T (°C) = temperature in °C.

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