Estimation of Air Emissions from Diesel Engines on Drilling Rigs

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Estimation of Air Emissions from Diesel Engines on Drilling Rigs: *Emission inventory will allow the Wyoming Department of Environmental Quality (DEQ), Air Quality Division (AQD) to make better quality, scientifically based decisions concerning the formation of ozone (O3), visibility, and the contribution of Greenhouse Gases (GHGs) from the fast oil and gas developing area in south west part of the state. The purpose for the development of the inventory is to identify sources and types of emissions, emission estimation techniques, and the relative impact of different sources on the air resource within county and state boundaries. It has become crucial to identify the most accurate and cost effective methods for determining air emissions of drilling operations. Estimation is the preferred method for creating regional emission inventories since direct measurement of diesel engine exhaust is often cost prohibitive. These estimations are commonly calculated using engine load, conservatively estimated at 100%. This introduces considerable error in the emissions inventory since electric rigs are rarely run at full load and drilling engine activity dramatically varies from job to job. Conducting an air emission inventory of drilling rigs requires an innovative way to estimate emissions without relying on engine load as a primary variable. With this in mind we, (as part of the research team), employed an estimation method based on fuel consumption rather than horsepower. Fuel use data is readily available on drilling sites and so more accurately reflects the engine activity of electric rigs in drilling operations. This study finds that calculated emissions can vary from 9 to 106 pounds per hour, (4 to 48 kg per hour), of NOx depending on the estimation method used. Given the deviation that can occur in estimation, the fuel consumption method offers an opportunity for more accurate, cost-effective assessment of regional emission inventories.*

Key words: *air quality, emissions, air emission inventories, drilling rig emissions, emission estimation, diesel engine emissions.*

INTRODUCTION

An emission inventory of the Jonah Infill and Pinedale Anticline Development Area (JPDA) is currently being conducted for the nine consecutive years. Operators within the JPDA are asked to submit calendar year emissions information to the AQD no later than May 31st of the following year. The inventories list each well and/or PAD facility, condensate and gas production, emissions from individual sources, and what devices are controlled.

There are three main methods for collecting air emissions data for engines, one of the largest emitters. It can be directly measured at the engine tailpipe, it can be measured through ambient downwind monitoring, or it can be estimated through a collection of engine data, fuel data and emission factors for the family of engines being studied. Since direct emission measurement of all emission sources in an air emission inventory can be limited by funding, time, or staff size, estimation is typically used to determine the air quality impact from a particular industry, [1]. The current methods for estimating emissions impose significant error in the inventory thus compounding the variance between regional air shed models. These high levels of variance result from the quality of the data being entered into the equations as well as the equations themselves. As part of WY DEQ team, and the cooperation from the industry partners and University of Wyoming (UW) engineering department, we conducted study to determine the best way to estimate emissions from drilling operations via data collection directly from energy producers with active operations in the JPDA. We employed an alternative calculation that used fuel consumption data rather than total horsepower and engine load data. This method appeared to minimize the error significantly, giving a more accurate picture of drilling engine activity.

PRESENTING THE ISSUE

I. Planning and Data Collection

Initial meetings consisted of introductory presentations and a description of how emissions inventories are typically calculated. Operators became increasingly concerned about the accuracy of emission inventory methods; specifically that emissions inventories multiply total potential engine load by total available horse power. According to drilling engineers participating in the group, generator engines for electrical rigs rarely run at full engine load and there may be several engines located on site as back-up that are not running at all. Furthermore, since engine load can fluctuate dramatically during a drilling operation, standardization poses a sizable challenge with risk of significant error. Therefore, it was agreed that using fuel consumption as an alternative method to using total potential horsepower and engine load would yield a clearer picture of actual emissions. What resulted was a refined equation for estimating emissions from drilling rigs based on fuel consumption. Fuel consumption data was simpler to obtain than engine load data and could be acquired directly from the operators without site visits or the acquisition of highly sensitive engine controller data from the service providers. This is appreciable since most air emission inventories are survey driven and do not include site visits or nondisclosure agreements. Data was collected by submitting a survey to nine participating companies within Sublette County. Field data from the surveys were compared with default data from literature using the fuel consumption method as explained further below. Additionally, emission results from the fuel consumption method were compared with emission results from the horsepower method.

II. Data Analysis and Understanding Emission Factors

In order to understand how emissions are estimated, it is first necessary to understand emission factors. Emission factors are often averages of available data and assumed to be representative of all emissions within a certain source category. They are representative values which relate the quantity of pollutants released into the atmosphere to the activity releasing the pollutants and are expressed as the weight of the pollutant divided by unit weight, volume, distance, or duration of the activity emitting the pollutant, [1]. The emission factor is used to calculate the total emission from a source as an input for an emission inventory, [1]. The general USEPA (2014) equation for emission factor development is:

$$E = A \times EF \times (1 - ER/100),$$

where E = emissions; A = activity rate; EF = emission factor; ER = overall percentage emission reduction efficiency.

General emission factors are available to the public. However, variations in engine conditions can significantly affect the emissions at an individual location depending on temperature of combustion or emission controls; the development of local emission factors is highly advantageous and will provide more accurate estimations, [1]. Emissions of criteria pollutants are usually given as mass of pollutant emitted per mechanical energy produced by the engine, (i.e. g/kWh). The energy developers participating in the study reported using Caterpillar 3512C diesel generator sets that were rated Tier 2. Emission values that were most representative of 3512C engines were found on the California Air Resources Board (CARB) certificate, [2]. These criteria pollutant values were derived from zero hour steady state emissions tests performed by the manufacturer on 3512C engines operating at nominal power and speed. Slightly more conservative than CARB, the USEPA also publishes emission standards that may be used as factors for this particular engine make and model. These values constitute allowable emissions when factors such as engine deterioration and less than nominal operational conditions are taken into consideration. These values may be used in lieu of the CARB certificate values but are generally much more conservative. Next there are the USEPA AP-42 which publish much generalized factors for engines greater than 750 horse power, [3]. The AP-42 divides the values into controlled and uncontrolled factors for oxides of nitrogen or NOx. Controlled factors account for associated emission controls on large engines, while uncontrolled factors make the assumption that the engine has no emission controls for NOx (ie tier zero). Table 1 gives the range of various emission factors and standards that are allowable for use when conducting an emission inventory with the aforementioned engine type. Note that both USEPA emission standards and CARB emission factors combine the NOx and volatile organic compounds (VOCs) into a single number which is referred to as non-methane hydrocarbon plus NOx (NMHC+NOx) in Table 1. The CARB Air Quality Management District guidelines outlined in Moyer (2005) were used to separate the two values into NOx and VOC which states that emission factors for NOx equals 95% of the total sum NMHC+NOx, [4]. The VOC values for AP-42 NOx controlled and uncontrolled engines were obtained from an USEPA total organic carbon (TOC) value which according to the USEPA (1996) is 9% methane and 91% non-methane by weight, [3]. Therefore, the original TOC values of 0.43 were adjusted for both controlled and non-controlled engines by multiplying 0.91. The remainder of criteria pollutants (VOCs, CO and PM) are the same for both controlled and uncontrolled engines because the "controls" in USEPA (1996) refers to NOx only, [3].

Table 1. Allowable Emission Factors and Standards (g/kWh) for Emission Inventories of Caterpillar 3512C engines as listed by USEPA, CARB, and AP-42 Sources

Emission Factors/Standards	NMHC NOX	NOX	VOC	PM	CO
Caterpillar 3512C Emission Factor CARB	5.3	5.04	0.27	0.14	1.6
Caterpillar 3512C Emission Standard - USEPA	6.4	6.08	0.32	0.2	3.5
AP42 Controlled Engine greater than 750 hp		7.91	0.43	0.43	3.35
AP42 Uncontrolled Engine greater than 750 hp		14.6	0.43	0.43	3.35

III. Results and Making the Comparison

Calculations were performed for each of the criteria pollutants using each of the protocols: Calculations using fuel consumption method with field data; Calculations using fuel consumption method and default data; Calculations using the traditional horse power method, [3]. Results as listed in Table 2 and Figure 1 indicate that pounds of pollutants reported for the same operation could vary as much 97.21 pounds, (44 kg), depending on the protocol chosen.

Table 2. Emissions Results of Two Estimation Methods Using Available Factors and Standards(lb/hp-hr)

	Fuel Consumption Method		Traditional Horsepower Method	
	Field Data and CARB Emission Factor	Default Data and USEPA Emission Standard	AP-42 NOx Controlled Emission Factor	AP-42 NOx Uncontrolled Engine Emission Factor
NOx	9.11	14.74	57.60	106.32
VOC	0.48	0.77	2.84	2.84
PM	0.25	0.48	3.13	3.13
CO	2.89	8.49	24.40	24.40

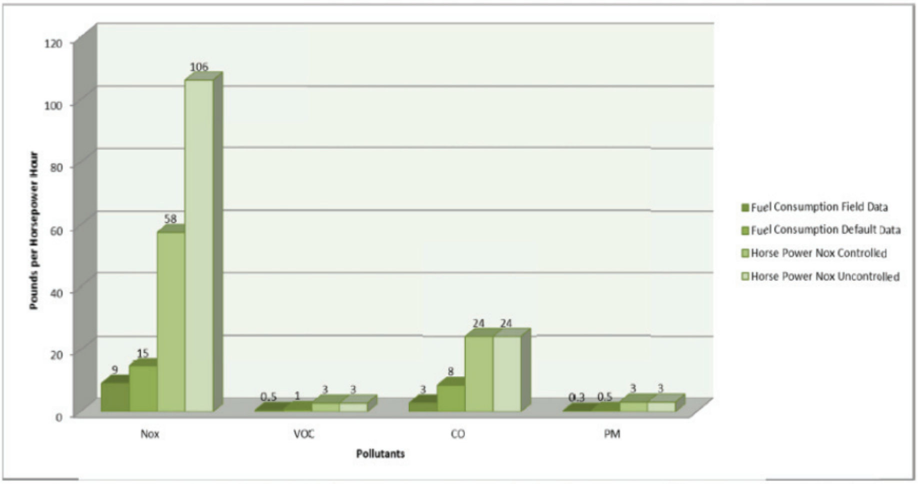

Figure 1. Comparison of Air Emission Inventory Protocols for the Same Drilling Operation (lb/hp-hr)

IV. Discussion

For the same operation, results varied from 9 to 106 pounds per hour, (4 to 48 kg per hour), for NOx depending on the protocol chosen. On average, using fuel consumption to calculate emissions rather than total horse power yielded a lower pound per hour rate, (kg per hour). This was expected since the horse power method was reliant upon a default 100% engine load and assumed that generators were all operational at all times. Estimating emissions with the fuel consumption method uses data that more accurately reflects engine activity under field conditions.

With that said, the question becomes – if the fuel consumption method yields more accurate results for drilling operations, then why not use this method for hydraulic fracturing operations as well? The answer is that data availability varies depending which operation is being studied. On a hydraulic fracturing site, acquiring fuel consumption data for individual engines (such as the hydraulic fracturing pumps for instance) can be quite challenging since fuel is typically supplied by 1 or 2 tanker trucks and then routed throughout the pad for a whole host of activities and many types of equipment. Engine load from fracturing pumps however remains fairly stable and can be estimated with some degree of confidence. Therefore, using the horsepower method may be the best option in that situation.

In a drilling operation however, it is the opposite. Fuel consumption data is fairly simple to obtain since only 2 or 3 generators supply power for the electric rigs. Whereas drill rig generator engine load is highly variable; changing dramatically throughout the job and adjusted to account for well depth, geologic formation, type of petroleum product being extracted, type of well drilled, type of mud used, type of equipment used and company philosophy. So for this type of activity, it might be best to consider using the fuel consumption method.

CONCLUSION

Oil and gas drilling and production emissions have, in the past, been grouped into the "area source" category where their boundaries are typically county lines. Averaging emissions across a county – when, for example, 90% of emissions come from sources located on 10% of the surface area – can significantly reduce the impact of those emissions locally in modeling applications. More narrowly defining the area where the emissions come from will help more accurately project where air impacts will occur. Area source inventories will need to be updated on an annual basis as new wells are drilled and placed into operation, pressures at existing wells decline, and old wells are either shut-in or plugged and abandoned.

The impact of clustered large NOx emission sources (such as drill rigs) combined with smaller, more dispersed VOC sources (such as production sources) on ozone formation must be assessed to understand episodic wintertime ozone. Due to wildlife concerns in the northern portion of the Pinedale Anticline, drilling in this area is limited during the winter months. As a result, drill rigs are moved to the southern portion of the Anticline. In the southern area the elevation is lower and the drill rigs are closer to the rigs operating within the Jonah Infill. This increases the density of NOx sources in a relatively small area. Therefore a number of factors must be gathered and tracked on real-time basis when preparing emissions inventories. A further concern is how emission factors are derived for each rig engine. Actual emission rates may vary significantly from engine to engine, even if they are of the same type.

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The paper has been reviewed.
Докладът е рецензиран.