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Project Summary

Assessment of Oil Production Volatile Organic Compound Sources

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Emissions of volatile organic compounds (VOC) from oil production in new fields were estimated based on three types of information: (1) extent of new oil and gas fields (those that started production after 1974) in the contiguous 48 states, (2) drilling techniques used for oil and gas exploration and production wells (and their VOC potential), with specific emphasis on the drilling fluids, and (3) equipment and techniques for oil and gas production in new fields and their potential VOC sources.

The complete record obtained from the U.S. Geological Survey Petroleum Data System (PDS) has been provided for post-1974 oil and gas production within the 48 contiguous states. Verification and updating of PDS has been accomplished for all but nine states.

A description of oil and gas exploration and production drilling technology is presented. Emphasis has been placed on the makeup, use, and disposal of drilling fluids. A simple model for assessment of VOC emissions accompanying drilling is presented along with an estimation of the potential VOC emissions associated with drilling activities.

Quantification of the VOC emissions associated with oil and gas drilling and production technology was hampered by lack of data in several areas. Recommendations for further efforts are presented so that the assessment of potential VOC emissions can be made by state, county, or field.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Petroleum production represents a large potential source of volatile organic compound (VOC) emissions. This effort was intended as a step toward obtaining sound estimates of the amount of VOC emissions associated with new field (after December 1974) oil and gas exploration and production in the 48 contiguous states. The program consisted of a survey with the following tasks:

1. Determination of the new oil and gas fields in the 48 states that have started primary production after December 1974.
2. Determination of the VOC emission potential and techniques for drilling gas exploration and production wells and the handling of drilling muds.
3. Documentation of equipment and techniques in use for the assessment and quantification (to the extent possible) of potential VOC sources (including mud operations, waste oils, and fugitive emissions from operating equipment). Five new oil and gas fields were visited.

Current practices in well-drilling techniques, drilling and workover fluids, and well servicing and workover are discussed, and a survey of new fields is described. The survey data are used in conjunction with drilling information to define prospective VOC sources, and the VOC forecast is made.

Current Drilling Techniques for Oil and Gas Wells

A brief review of well-drilling techniques and equipment now in general use is presented. Rotary drilling and cable tool drilling are described, but basic drilling equipment and rig components, drilling operations, and auxiliary rig equipment are detailed only for the rotary drilling process.

The components associated with a modern drilling rig are discussed in terms of the four basic tasks the rig is expected to accomplish: (1) producing and transmitting power, (2) hoisting equipment for the drilling string, casing, and tubing, (3) rotating the drill string and bit, and (4) circulating drilling mud to remove cuttings and maintain a safe hydrostatic pressure in the well bore.

Prime power sources for modern drilling rigs are almost always diesel-electric. Most rigs require from 0.75 to 2.2 MW supplied by two or more engines, depending on the depth to be drilled and the rig design. The electricity generated is sent to electric switch and control gear and then used to power electric motors for the draw works, rotary table, and mud pumps.

During the drilling process, the drill string is often hoisted from the well bore and disassembled to replace worn drill bits, run casing into the well, test formations, take core samples, etc. The string is then reassembled and run back into the hole. This cycle is accomplished by the hoisting equipment (or the drawworks), consisting of derricks and masts for support and a block and tackle system.

Rotary equipment comprising the swivel assembly, the kelly, rotary table, the drill string, and the drill bit are described.

The drilling mud circulation and treating system is discussed. Drilling mud is pumped down into the well hole through the drill string, jets out from the drill bit, and flows upward out of the hole in the annulus formed by the drill pipe exterior and the wall of the hole. Cuttings are removed from the drilling mud by shale shakers. One of the primary purposes for the use of drilling mud is to provide a safe hydrostatic pressure in the drill hole to avoid blowouts. A number of safety valves, or blowout preventers, are located in the mud circulating system and are controlled so as to shut off the drilling mud flow and seal the system to prevent a blowout if high-pressure formation fluid is encountered.

The basic drilling operations are briefly described: The setting of the conductor pipe, blowout preventers and recirculation of drilling mud to initiate the rotary drilling process, the installation of surface casing, drilling and adding new drill pipe to the drill string as the hole deepens, and running and cementing casing down to the promising formation, where, if evidence warrants, the production string is run into the hole. Well completion details are also presented.

Drilling Muds

A review of drilling muds is included and covers water-based and oil-based mud composition, factors affecting the type of drilling fluid used, factors affecting the quantity of mud and cuttings generated, and disposal of solid, liquid, and gaseous wastes produced in the drilling process.

Among the mud components discussed are weighting material, clays, dispersants (to lower viscosity, gel strength, and filtration rates), organic polymers (to aid in hole-cleaning, barite suspension, and filtration control), inorganic chemicals (to control alkalinity, calcium ion concentration, scavenging oxygen and sulfide, and corrosion), surfactants, lost circulation materials (to plug highly permeable formations and avoid excessive mud loss), biocides, salts, and oils.

Often the composition of the formation to be drilled determines the type of mud that should be used. Some formations, such as shales, may require a special mud to avoid excessive hole enlargement, whereas others such as sands may result in the buildup of a filter cake as the water base runs into the porous formation.

Other formation properties that can determine the type of mud additives used are the formation pore pressures anticipated, formation fluids (such as salt water), hydrogen sulfide, and formation temperature.

The mud volume and cuttings generated by the drilling process can be a problem in soft shales containing swelling-type clays or in water-soluble formations. Brine-based or oil-based muds can be used if the problem is quite serious.

Several commonly used methods of disposing of waste drilling mud and cuttings are presented and very briefly discussed.

Completion and workover fluids are often the same fluids (muds) that were used in drilling the well. Special completion fluids are used, however, when drilling mud solids would create problems of productivity damage, settling or solidification in annulus, or corrosion. Salts, organic polymers, corrosion inhibitors, a buffering agent, and defoamers are briefly detailed as components of typical solids-free fluids. Solids-laden systems are also mentioned.

Oil Well Servicing and Workover

As oil or gas wells age, production problems develop. Tubes plug with sand, a subsurface pump may fail, reservoir pressure may decline, and well casing may corrode. At this stage, oil well servicing and workover is required to correct and repair the well and the equipment.

The servicing and workover rigs are mobile. Truck-mounted rigs are used for light- and medium-duty tasks, but for heavier work required by deeper wells, the equipment will be designed into self-propelled carrier units developing more than 0.45 MW (600 HP) and capable of hoisting more than 114,000 kg (250,000 lb).

Descriptions are given of the types of remedial well work (swabbing, pump repair production tubing replacement, repair of packers), well cleanout (sand cleanout, casing repair, sidetrack drilling, drilling deeper) and well stimulation (explosives, acid stimulation and hydraulic fracturing).

Survey of New Oil and Gas Fields, 1975-1979

Information was gathered for the contiguous 48 states (onshore fields only), with data limited to fields that went into production after December 1974. The data were obtained from the Petroleum Data System (PDS), a storage and retrieval system sponsored by the U.S. Geological Survey, and from state files. Oil and gas agencies or divisions of geology of all contiguous 48 states were contacted, as these agencies regulate oil and gas drilling and production. The annual reports of these agencies were requested for the years 1975-1979. The drilling and production data to be acquired for each new field is as follows:

1. Field name and operator(s) in field
2. Formation/reservoir
3. County
4. Primary production start date (January 1975 or later)
5. Type of field (oil, oil/gas, gas) and API gravity (where applicable)
6. Well depth, feet
7. Producing zone, feet (or least and greatest depth)
8. Number of wells as of recent date (state date)
   a. Producing
   b. Exploratory
   c. Abandoned
9. Annual production for 1975, 1976, 1977, 1978, and 1979 of:
   a. Crude oil (bbl)
   b. Condensate (bbl)
   c. Nonassociated gas ($ft^3 \times 10^6$)
   d. Associated gas ($ft^3 \times 10^6$)
   e. Water (bbl)

The states varied greatly in their publications. The printed reports disseminated were often incomplete or not in a form suitable for this study (e.g., production by county, not by field).

Twenty-one of the 48 states have no new fields. In 18 of the states with new fields, state data were scanned, identified, edited, and added to the PDS computer compilation. The limited scope of this project did not permit completion of such tasks for the nine remaining states with new fields; the PDS compilation and partially processed state data for the nine states are preserved.

The information headings listed earlier are presented on a statewide basis (18 states) in several tables of the full report. Selected information is given in Table 1 for the 18 states.

VOC Emissions for Oil and Gas Drilling Operations

The emissions addressed in this study are from formation fluids, high-pressure formation gases, and H_2S from troublesome formations. Formation gases entering the drilling mud will be removed in the shale shakers, degassers, mud pits, choke manifold (around the blowout preventers, when necessary), and in small quantities from valves, flanges, and fittings. VOC emissions will be sporadic and negligible until certain troublesome formations are penetrated; then emissions will depend on the skill of the drilling crew and mud handler in plugging such a formation. Once such a formation is plugged or permanently sealed off with well casing, the VOC emission rate will again decline.

Data are given on the number of oil and gas wells drilled and the number of drilling rigs in operation (drilling activity) from 1974 through 1979.

Model for Drilling Operations

A model for VOC emissions occurring during drilling operations is given that includes (1) the oil and gas brought out of the well in the pores of the rock cuttings removed from the producing zone, (2) the leakage of oil and gas into the drilling mud multiplied by the length of time the producing zone is directly exposed to the mud (no means of estimating the leakage rate is given), and (3) the rate of loss of diesel fuel oil from oil-based mud multiplied by the length of time the oil-based mud is used.

Estimates were made of the order of magnitude of the VOC emissions occurring during the drilling of oil and gas wells. With data given for 1979 on the total number of wells and footage drilled in the 48 contiguous states (excluding offshore drilling) and the average number of active drilling rigs for 1979, the average depth drilled per day was calculated. This figure was used with new field data for five states (Table 2). If it is assumed that the average well diameter is 0.23, the formation porosity is 0.2, the oil and gas density is 600 kg/m^3, and the thickness of the producing zone is that given in Table 2, the total amount of oil and gas (VOC) removed from the well in the cuttings ranges from 51.7 to 91.5 kg (Table 3). The average VOC emission rate per day ranged from 2.0 to 6.2 kg (Table 3).

Table 1. *Statewide New Field Data: Fields, Wells, Depth, Gravity*

	New Fields			No. Wells in New Fields					
State	*Total*	*Oil*	*Gas*	*Producing*	*CAPDG**	*Shut In*	*Average Depth, m (ft)*	*Average Pay Zone, m (ft)*	*Average API Gravity*
Alabama	*23*	*11*	*21*	*102*	*0*	*0*	*3,014 (9,889)*	*5.2 (17)*	*40*
Arkansas	*62*	*50*	*18*	*2,174*	*0*	*0*	*1,853 (6,078)*	*6.7 (22)*	*36*
Colorado	*107*	*58*	*57*	*138*	*0*	*11*	*1,734 (5,689)*	*9.1 (30)*	*38*
Florida	*4*	*4*	*1*	*3*	*0*	*3*	*3,934 (12,906)*	*4.9 (16)*	*31*
Illinois	*96*	*NG+*	*NG*	*>151*	*(total wells)*		*1,352 (4,435)*	*NG*	*18*
Indiana	*1*	*1*	*0*	*0*	*2*	*0*	*344.4 (1,130)*	*NG*	*NG*
Kentucky	*18*	*>11*	*>3*	*>32*	*(total wells)*		*569.7 (1,869)*	*NG*	*NG*
Louisiana	*35*	*8*	*29*	*55*	*4*	*8*	*3,324 (10,906)*	*6.7 (22)*	*47*
Michigan	*141*	*>79*	*>28*	*169*	*22*	*1*	*1,623 (5,325)*	*NG*	*50*
Mississippi	*91*	*>62*	*>15*	*123*	*12*	*19*	*3,667 (12,030)*	*11.3 (37)*	*41*
Montana	*99*	*55*	*45*	*419*	*0*	*104*	*2,720 (8,924)*	*7.9 (26)*	*40*
Nevada	*1*	*1*	*0*	*14*	*0*	*0*	*1,246 (4,087)*	*NG*	*27*
Oregon	*1*	*0*	*1*	*5*	*0*	*0*	*833 (2,700)*	*183 (600) (sands)*	*NA‡*
Pennsylvania	*26*	*NG*	*NG*	*NG*	*NG*	*NG*	*1,165 (3,823)*	*NG*	*NG*
South Dakota	*2*	*2*	*0*	*2*	*0*	*0*	*2,728 (8,950)*	*3.05 (10)*	*33*
Texas	*4,208*	*>1,408*	*>1,922*	*6,392*	*4,303*	*0*	*2,276 (7,468)*	*NG*	*42*
W. Virginia	*21*	*0*	*21*	*21*	*0*	*0*	*1,095 (3,591)*	*4.6 (15)*	*NA*
Wyoming	*6*	*NG*	*NG*	*NG*	*NG*	*NG*	*2,880 (9,450)*	*18.6 (61)*	*24*

**Capable of producing.*
+Not given.
‡Not applicable.

Table 2. *New Field Data Summary*

State	*Average well depth drilled/day m (ft)*	*Producing zone, Δ m (Δ ft)*	*Producing zone interval / Average well depth* $\left(\frac{\Delta m}{m}\right)$
Alabama	*3,014 (9,887)*	*5.2 (17)*	*0.00172*
Arkansas	*1,853 (6,078)*	*6.7 (22)*	*0.00362*
Colorado	*1,734 (5,689)*	*9.1 (30)*	*0.00527*
Louisiana	*3,324 (10,906)*	*6.7 (22)*	*0.00202*
Montana	*2,720 (8,924)*	*7.9 (26)*	*0.00291*

Table 3. *Estimated VOC Emissions from New Field Well Drilling*

State	*VOC/well (kg)*	*Average well drilling time (days)*	*Average VOC/ well per day (kg)*
Alabama	*51.7*	*25.7*	*2.0*
Arkansas	*66.9*	*15.8*	*4.2*
Colorado	*91.5*	*14.8*	*6.2*
Louisiana	*67.0*	*28.3*	*2.4*
Montana	*78.8*	*23.2*	*3.4*

The contribution of the leakage rate of oil and gas from the producing zone into the drilling mud is unknown.

Model for Production Operations

The emissions during production operations are primarily fugitive, and the equipment components comprise valves, connections, pumps, compressors, meters, hatches, diaphragms, and pits. The following model is applicable:

$$\underset{\text{kg/day}}{\text{Emission Rate}} = \Sigma \underset{\substack{\text{No. of}\\\text{components}}}{\begin{pmatrix}\text{component}\\\text{inventory}\end{pmatrix}} \underset{\substack{\text{kg/day/}\\\text{component}}}{\begin{pmatrix}\text{emission rate}\\\text{per component}\end{pmatrix}}$$

The emission rate per component for production operations has been developed by Rockwell under the sponsorship of the American Petroleum Institute (W.S. Eaton et al., 1980. *Fugitive Hydrocarbon Emissions from Petroleum Production Operations*, 2 vols. American Petroleum Institute.)

Conclusions

1. Drilling activity in 1980 will surpass the activity of the last several years, with an estimated 13,607 exploratory wells to be drilled.
2. Drilling has made many technological improvements in the past several decades, but the basic rotary method remains the one most often used.
3. VOC emissions from oil and gas exploration and production drilling are small, although several potential sources of VOC emissions (entrained gas and oil in drilling fluids, emissions from oil-based muds, and the number of valves, flanges, etc. associated with fuel systems) are not well defined. The VOC emissions calculated using simple assumptions are less than 10 kg per well per day.
4. Reporting of state oil and gas production information is not uniform from state to state and is not up to date.
5. The number of new fields reported yields a general estimate that can be useful, but the different definitions used by the individual states makes a direct comparison difficult. The collected information is adequate for use as a parameter and estimate of the VOC potential if a satisfactory model is developed for the VOC emissions associated with an oil and gas well or field.
6. Additional data in several key areas are required to estimate the VOC emissions associated with oil and gas well drilling and production. These areas are (a) drilling (including data on emissions from mud degassing and oil-based muds and the number of components within the fuel gas system) and (b) oil and gas production (including a model of major subsystems (e.g., compressor) that will allow estimates of components and application of currently developed emission factors).

Recommendations

1. Measurements should be made to verify the magnitude of the estimated VOC emission values presented in this study.
2. Further efforts should be devoted to defining VOC emissions more accurately for representative new oil and gas facilities or sites. These efforts should include a survey of additional sites to establish one or more models for assessing potential VOC emissions.
3. Component population estimates obtainable from photographic documentation should be supplemented with stream composition data so that existing emission factors can be applied.
4. Oil and gas production data from new fields should be verified beyond the information presented in this report.

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The complete report, entitled "Assessment of Oil Production Volatile Organic Compound Sources," (Order No. PB 82-108 176; Cost: $8.00, subject to change) will be available only from:
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