Atmospheric Emissions From Oil And Gas Extraction And Production In Greece

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Abstract.

This paper addresses the atmospheric emissions from oil and gas extraction and production in Greece. The study was carried out in 2014 in the Kavala gulf, which currently is the only location of oil and gas production in Greece and where the exploration activities for hydrocarbons started in the late '60's. This study presents the qualitative and quantitative characteristics of atmospheric emissions, in relation also to the emissions control management system. Currently, atmospheric emissions during extraction and production of hydrocarbons in Greece are very low and do not have any significant effect on air quality and climate change. Particular reference is made to sulphur compounds, since the existence of volcanic rocks results to increased amounts of H_2S. Despite the fact that the produced gas in Prinos reservoir contains about 40% hydrogen sulfide, SO_2 emissions are very low due to the applied technology for transforming hydrogen sulfide to sulfur and the integrated emissions control management system.

Keywords: Oil and gas production, Atmospheric emissions, Greenhouse gases, Gas Flaring, H_2S

1. Introduction

Oil and gas exploration in Greece begun in 1969, when the State granted hydrocarbon exploration concession rights, in the Gulf of Kavala, to a Consortium of foreign companies. The first well drilling in the region was the «EAST THASSOS-1» in 1971 and the next year (1972) the "SOUTH KAVALA" natural gas reservoir was discovered. Nowadays, there are three sour crude oil reservoirs in Prinos area and one sweet gas reservoir in south Kavala (Kavala Oil S.A., 2016a) The present work focuses on atmospheric emission from the Prinos facilities in 2014. In order to fully understand the potential impacts of oil and gas extraction upon the environment it is important to understand the activities involved (E&P Forum/UNEP, 1997) The facilities in cases such as that of Prinos are developed both offshore and onshore and the produced fluid is transported through pipelines from offshore to onshore (Figure 1). Onshore facilities account for the final processing of the oil and gas streams into stabilized crude oil, natural gas, natural gas liquid and elemental sulfur. The total of atmospheric emissions from the oil and gas production industry in 2014 originate from the facilities of the gulf of Kavala. The average oil and gas production of 2014 was 1,486 bopd (Kavala Oil S.A., 2016b). For the following years a new investment programme will be in progress, in order to increase the current production up to 20,000 bopd (Energean Oil and Gas, 2016). Hence, it is essential examine the current situation and to provide insight so that in the future the oil and gas industry's activities in Greece will meet the atmospheric emission and air quality standards, through applying an integrated programme for the monitoring and control of atmospheric emissions

Figure 1 Region of Prinos in Kavala gulf, East Macedonia/,Thrace, Greece

2. Air emissions

In most oil and gas reservoirs, initially the fluid flows naturally to the surface under the bottom hole pressure. When the produced fluid reaches the surface, it is driven to the separation units. Particularly the crude oil is separated from the dissolved gas (associated gas) and the hydrogen sulfide (H_2S) and is then stored in order to be loaded in tankers. The extraction and storage process results to three main types of atmospheric emissions: combustion gases, fugitive emissions, as a result of the storage of fluids in tanks, and chlorofluorocarbons coming from refrigeration systems. The types of atmospheric emissions are described in Table 1. The most significant emissions from the production oil and gas in Greece are carbon dioxide (CO_2), sulfur dioxide (SO2) and nitrogen oxides (NO_x).

Table 1 Air emission sources and components of Greek oil and gas extraction and production (Kavala Oil S.A, 2016)

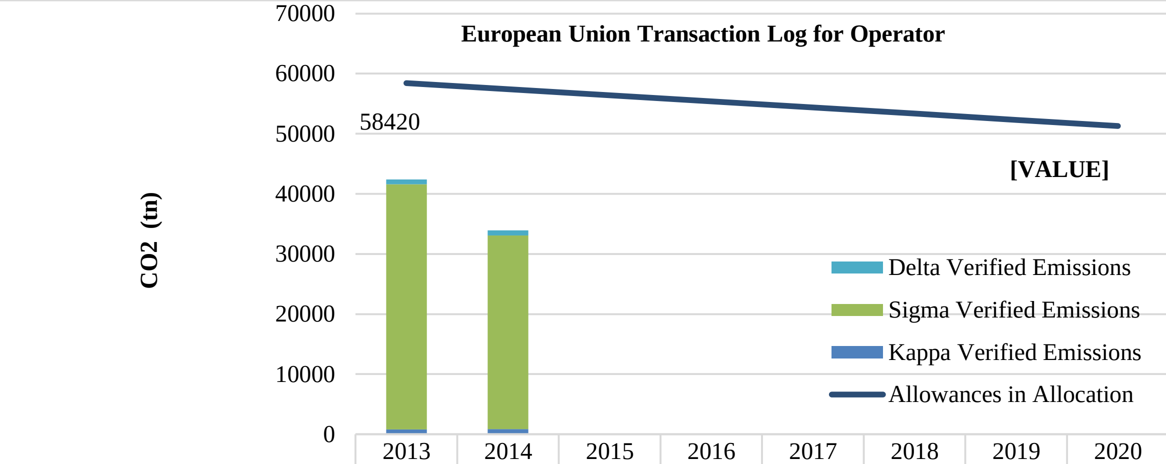
Emissions from energy production (conversion) or power generation	Combustion of gas	CO_2, NO_x, SO_2
	Combustion of diesel	CO_2, NO_x, SO_2 , Pm10, Pm 2,5 , CO and nmVOC
Emissions from storage and loading of oil	CH_4 & nmVOC	
Fugitive emissions	CH_4 & nmVOC	

2.1 CO2 emissions

CO_2 emissions exist during all combustion processes and are a function of the carbon number of the fuel used. The major sources contributing to CO_2 emissions are boilers, in which fuels are oxidized in order to generate heat for internal use, and turbines (gas turbines), used for power generation (Romi , vel-Cerovec-ki, 2000). Field-specific emission factors are used, thus reducing the percentage of uncertainty in estimating the atmospheric emission inventories (European Commission, 2012, 2013). Annual greenhouse gas emissions in Greece were 34933.8 tn CO_2 in 2014 (Figure 2). These inventories are verified by authorized external auditors, according to Regulations 600/2012/EC and 601/2012/EU. Emissions of greenhouse gases from offshore facilities (Delta complex & Kappa) during 2014 were 1684.3 tn CO_2, which equals to 4.82 % of total emissions (Figure 2). It should be noted that in offshore facilities the major CO_2 emissions are due to gas flaring, glycol dehydrators, electricity generator and diesel gas compressor. In terms of onshore facilities (Sigma), the main emission sources are the direct-fired boilers, the super heater and the sulfur tail gas incinerator of the Sulfur Plant (two Claus units in parallel and three sulfreen type batch reactors). Turbines have not been used since 2010, therefore they are not included in the greenhouse gas emissions for the year 2014. The CO_2 emissions of combustion engines are calculated using the standard tier uncertainty estimation methodology, using appropriate emission factors. Particularly Tier 2a IPCC has been used to estimate emissions from fuel combustion by source subcategories. Moreover field-specific emission factors were available from the analysis of the composition. To derive the emission factor of CO_2 a detailed analysis of the hydrocarbon composition was performed. The CO_2 emission factor used in the calculations of the fuel gas domestic mixture is equivalent to 56.95 tn CO_2 / TJ (Ministry of Environment and Energy, 2016). Figure 3 presents the historical trend for direct and indirect CO_2 emissions per barrel per day of hydrocarbons delivered in the 2000-2014 period. The data from the period 2000 to 2014 revealed that the trend of oil production was linearly decreasing, while CO_2 emissions were rising for the same period. In addition, emissions of CO_2 decreased by 67.73% for 2014 as compared to CO_2 emissions in 2008. It is also observed that for the years 2007, 2008 and 2009, oil production was quite low. On the other hand, CO_2 emissions presented maximum values. One possible reason could be that more energy is required to extract the oil and gas from the reservoir, due to more energy demanding activities (Skjerpen, Gavenas-, Rosendahl, 2015). In our case study, this is probably attributed to the fact that during these years, turbines were operated (both electricity and heat). Then, in 2010, the operator decided to close all the turbines in order to cover the energy demand with natural gas provided by the Public Gas Corporation (DEPA) for financial and technical reasons (Kavala Oil S.A., 2016a). To sum up, the CO_2 emissions of oil and gas production are mainly due to the operation of boilers using sweet gas, to diesel combustion engines, to boilers for glycol regeneration using sour gas, and to flaring.

2.2 Sulfur emissions (H_2S and SO_2)

Emissions of sulfur dioxide are related to the sulfur content (%) of the fuel and calculated based on the H_2S content of the gas, which is indicated in ppm. The composition of hydrocarbons depends on the geological formations in each region and affects the quantity of SO_2 emissions. SO_2 emissions from oil and gas extraction and production in Greece are important owing to the existence of significant percentage of hydrogen sulphide (H_2S) in volcanic rocks. The average content of H_2S in the deposit reservoirs of Kavala Gulf ranges from 35% to 40% (Varotsis, 2010). Emissions of sulfur dioxide (SO_2) from the offshore installations (Kappa & Delta complex) in 2014 were 1517 tn, which is equivalent to 79.13% of the total emissions (Figure 4). The main source of SO_2 was the flare; sweet gas and a small amount of sour gas was burnt in the process of water treatment. Since combustion engines were using diesel with a very low sulfur content (ultralow diesel sulfur), their emissions have not been calculated for the annual inventory. On the contrary, at the onshore facilities (Sigma), the Sulfur Plant converts 99% of the H_2S included in the sour gas to sulfur. As a result, the produced natural gas is low in sulfur content and is used as fuel for energy production. Hence, the emissions of SO_2 at the onshore facilities were very low, as shown in Figure 4.



	2013	2014	2015	2016	2017	2018	2019	2020
Delta Verified Emissions	808,0	833,8						
Sigma Verified Emissions	40759,4	32249,5						
Kappa Verified Emissions	811,1	850,5						
Allowances in Allocation	58420	57404	56387	55370	54354	53338	52321	51305

Figure 2 Comparison of CO_2 emissions inventory (tn) with allocated allowances in the EU emissions trading system

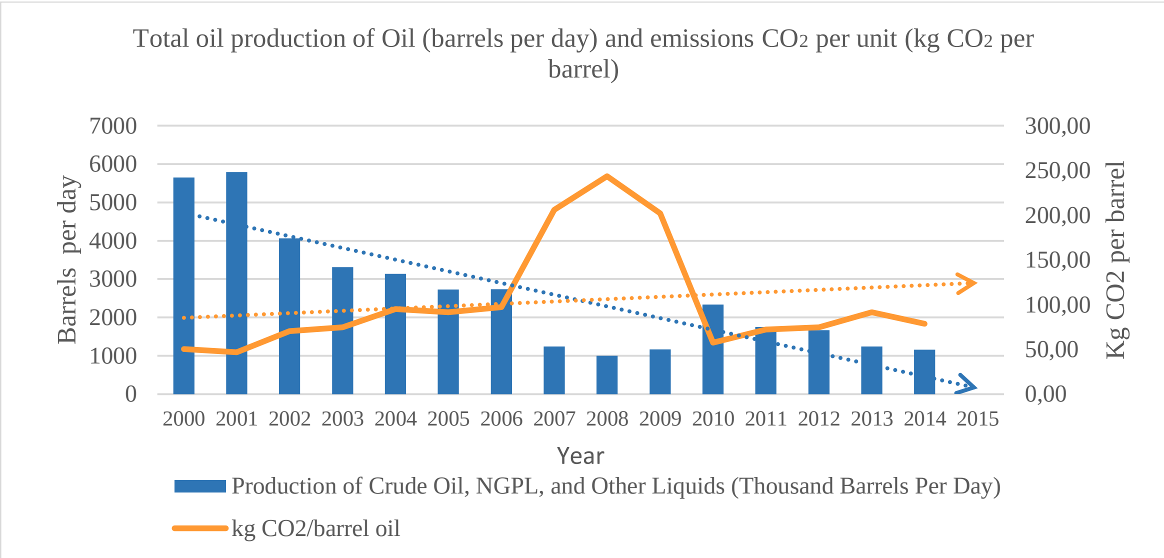


Figure3 CO_2 emissions and Oil and Gas Extraction in Greece for the period 2000 – 2014 (U.S. Energy Information Administration International Energy Statistics, 2016 & Ministry of Environment and, Energy and Climate Change, 2014)

The main source of sulfur emissions at the onshore facilities is the incinerator stack where the sulfur unit tail gas is safely burned. H_2S measured concentrations have a maximum value of about 15 ppb (0.015ppm) or 0.0225 mg/m^3. The operator uses the limit of 10 ppm time-weighted average (TWA), according to OSHA Standards (Kavala Oil S.A, 2016b). Since hydrogen sulfide is a key parameter for the daily operation of the facilities. H_2S concentrations are measured to ensure the protection of the employees and of the inhabitants of the surrounding region. The ambient concentration measurements of H_2S due to the twelve total sulfation monitoring stations in different onshore locations and one central environmental monitoring station close to the onshore facilities, suggest that H_2S emissions are negligible. Natural gas is used as a fuel to cover energy needs at the onshore facilities and is the main reason for the very low, almost insignificant, emissions of NOx from the oil and gas production in Greece. The NOx emission factor is equivalent to 0.003 kg NOx / Nm3 natural gas, for all combustion engines, while the NOx coefficient for turbines is equivalent to 0.006 kg NOx / Nm^3 natural gas. NOx are emitted by diesel combustion engines, by drilling rig engines, by flares and by the dehydration process of sour gas. The biggest source of NOx emissions from petroleum activities in general, is combustion in engines at the onshore installations.

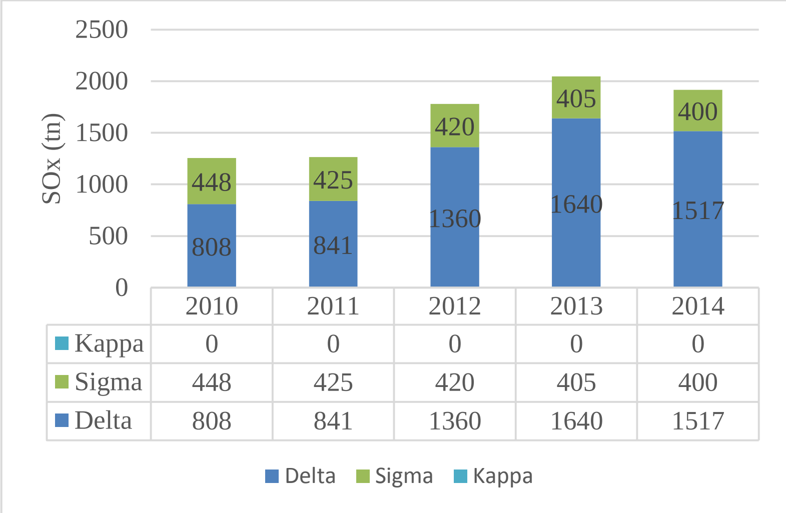


Figure 4 SO_x/SO_2 air emissions inventory of Oil and Gas extraction from 2010 to 2014

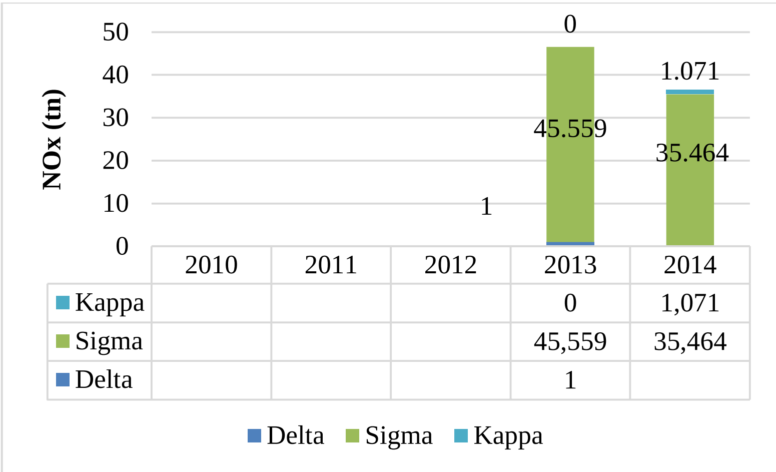


Figure 5 NO_2 air emissions inventory of Oil and Gas extraction for year 2014

2.3 Emissions of nitrogen oxides (NOx) and nitrous oxide (N_2O)

The total emissions of nitrogen oxides (NOx=NO+NO2) and nitrous oxide (N2O) at the offshore and onshore facilities, expressed as NO2 equivalent during 2014, were 36.535 tn (Figure 5). The emissions from onshore facilities accounted for 97.6% of the total emissions, as at the offshore facilities combustion engines for power generation (which are the main source for NOx and N2O) were not used. Onshore facilities are supplying electricity to the offshore installations through a submarine cable. Natural gas is used as a fuel to cover energy needs at the onshore facilities and is the main reason for the very low, almost insignificant, emissions of NOx from the oil and gas production in Greece. The NOx emission factor is equivalent to 0.003 kg NOx / Nm3 natural gas, for all combustion engines, while the NOx coefficient for turbines is equivalent to 0.006 kg NOx / Nm3 natural gas. NOx are emitted by diesel combustion engines, by drilling rig engines, by flares and by the dehydration process of sour gas. The biggest source of NOx emissions from petroleum activities in general, is combustion in engines at the onshore installations.

3. Conlusions

The monitoring of atmospheric emissions represents a critical component of the assessment of the environmental performance of oil and gas production and is necessary for ensuring a good air quality status and for protecting the health and safety of employees and the quality of life of the local population. Concentration measurements and emission inventories for the year 2014 from oil and gas activities in Greece confirm that emissions of atmospheric pollutants and greenhouse gases are very low and within the limits set by the national air quality standards and the European Union legislation. The examination of the CO_2 emission inventories for the years 2007, 2008 and 2009, showed that the main source of CO_2 emissions were the turbines. Emissions of CO_2 were low, since they are controlled within the framework of efforts of the European Union to reduce greenhouse gas emissions up to 2020, contributing to the global emissions reduction goals.The total offshore emissions (Delta complex) of sulfur dioxide (SO_2) are equivalent to 1517 tn for the year 2014. The majority of SO_2 emissions comes from combustion of sweet gas and a small amount of sour gas (process of water treatment) in the flare of the offshore facilities. In conclusion, the oil and gas industry in Greece has made significant progress in order to reduce emissions and protect the environment, with the use of emission control technologies and the continuous monitoring and assessment of atmospheric emissions and local air quality. However, since the establishment of the Hellenic Hydrocarbons Management Company S.A. in 2011 (Law 4001/2011), rights for exploration and exploitation of hydrocarbons are being granted in Greece, and it is expected that following this first stage, exploitation of hydrocarbons and oil and gas extraction and production will increase in the future. Therefore, it is necessary for decision-makers and operators to ensure environmental protection and the health and safety of employees and general population, *inter alia* through the development of appropriate monitoring systems and the use of up-to-date emission control technologies, establishing a closed optimization system.

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