SNAP CODE: **040501**

SOURCE ACTIVITY TITLE: **PROCESSES IN ORGANIC CHEMICAL INDUSTRIES (BULK PRODUCTION)**
Ethylene

NOSE CODE: **105.09.50**

NFR CODE: **2 B 5**

1 ACTIVITIES INCLUDED

Ethylene is produced by thermal cracking of petroleum fractions. These fractions can vary from ethane to heavy petroleum distillates.

2 CONTRIBUTION TO TOTAL EMISSIONS

The NMVOC emission of ethylene plants contributes 0.00 to 0.06% to the total NMVOC emission in any European country.

Table 2.1: Contribution to total emissions of the CORINAIR90 inventory (*28 countries*)

Source-activity	**SNAP-code**	**Contribution to total emissions [%]**							
		SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
Ethylene	040501	0	0	0.3	0	0	0.1	0.1	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)
- = no emissions are reported

3 GENERAL

3.1 Description

The feed is preheated in heat exchangers and brought to the reaction temperature of 750 - 850° Celsius by adding hot products and steam to the reaction furnace. Additional steam is added to dilute the reaction mixture. The residence time is kept short (about 0.1 sec.) to limit side reactions (coke formation).

After the reaction the gas mixture is quenched with cold oil, which in turn is used to produce steam. The oil gas steam mixture is separated in different fractions in a rectification section. In several steps the most important products of the mixture are separated. The low boiling products ethylene, propylene and the butylenes are separated after drying, compression and distillation.

For many applications ethylene must not contain acetylene. The acetylene is removed from the ethylene by selective hydrogenation.

After separation from the reaction mixture, ethane and propane are recycled to the reaction furnace feed, methane is used as fuel gas and hydrogen is used for hydrogenation (of acetylene).

The C-4 mixture is used as feed for the butadiene production.

The typical feed (ethane to heavy petroleum distillates) results in a production of about 36% ethylene, 13% propylene, 8% butylenes and 7% aromatics.

3.2 Definitions

3.3 Techniques

See section 3.1.

3.4 Emissions

The major emissions to the air are CO2, NOx, CO and hydrocarbons. The first three compounds are produced during the combustion of fuel gases in the reaction furnace, the hydrocarbons are mostly emitted due to leakage and flaring of the residual gases.

For the Netherlands all cracking processes together produce 4000 tons of VOCs per year. Ethylene is given a proportional share, being 36% of the total VOC emission. This emission, 1440 ton, is related to a production capacity of about 2700 kton ethylene per year and a realized production of about 2400 kton ethylene per year.

Emissions can be subdivided as follows:

Emission source	**[1]**	**[2]**
leakage losses from appendages, pumps, etc.	72%	75%
flaring, disruptions	18%	5%
losses due to storage and handling	1%	13%
combustion emissions	5%	<1%
other process emissions	4%	7%

About 73% of the VOC emissions can be considered as production independent (leakage etc. plus losses due to storage etc), but process operation time dependant (i.e. production capacity dependant). The other 27% is production dependant.

In a Canadian report [3] a subdivision specific for the emission from ethylene plants is given:

process	51%
fugitive	46%
storage and loading	1%
spills	1%

3.5 Controls

The losses due to leakage can be limited by use of certain types of seals and application of double seals near pumps.

4 SIMPLER METHODOLOGY

Use of an overall emission factor for ethylene production emissions. The amount of emitted VOC is then directly related to the ethylene production. For the Netherlands, 4000 ton VOC emission related to the thermal cracking activity, 36% ethylene in the thermal cracking product, and 2400 kton ethylene produced this would mean an overall emission factor of 0.6 ton VOC/kton ethylene produced.

5 DETAILED METHODOLOGY

A more detailed methodology is used by the United States EPA.

Instead of one emission factor for the whole plant, emission factors for each piece of equipment, such as valves, flanges, etc, can be used. Each type of equipment has its own emission factor. The total emission factor for the plant can be calculated by multiplying each equipment emission factor by the number of pieces of that type of equipment. Hence, for this method it is necessary to know how many pieces of each type of equipment are present in the plant.

In a Canadian study [3] the use of this methodology instead of the simpler one resulted in a considerably lower estimate of the process emissions.

6 RELEVANT ACTIVITY STATISTICS

Relevant statistics are the production capacity for ethylene and the realised ethylene production. Table 6.1 lists ethylene capacity and Table 6.2 production in several countries and regions (note that the countries statistics may not add up to the regional figures, since various sources of information have been compiled).

Table 6.1.: Ethylene capacities for some countries and regions for 1990

Country/Region	ktons/y	Source
China	1928	ChemWeek 12/2/92
Korea, South	1155	ChemWeek 12/2/92
Japan	5976	ChemWeek 12/2/92
Taiwan	845	ChemWeek 12/2/92
Thailand	315	ChemWeek 12/2/92
Africa + Middle East	3500	EurChemNews 23/3/92
Asia/Pacific	10900	EurChemNews 23/3/92
Eastern Europe	7900	EurChemNews 23/3/92
South America	3200	EurChemNews 23/3/92
USA + Canada	22000	EurChemNews 23/3/92
Western Europe	16500	EurChemNews 23/3/92

Table 6.2.: Ethylene production for some countries and regions for 1990

Country/Region	ktons/y	Source
Australia	1054	Chem&EngNews 29/6/92
Canada	2434	Chem&EngNews 29/6/92
China	1572	Chem&EngNews 29/6/92
Czechoslovakia	619	Chem&EngNews 29/6/92
France	2246	Chem&EngNews 29/6/92
Germany, West	3075	Chem&EngNews 29/6/92
Hungary	234	Chem&EngNews 29/6/92
Japan	5810	Chem&EngNews 29/6/92
Poland	308	Chem&EngNews 29/6/92
Romania	243	Chem&EngNews 29/6/92
Taiwan	776	Chem&EngNews 29/6/92
U.K.	1496	Chem&EngNews 29/6/92
U.S.A.	16556	Chem&EngNews 29/6/92
U.S.S.R.	3065	Chem&EngNews 13/4/92
Western Europe	14400	EurChemNews 27/4/92
Western Europe	12223	UN Statistics 1990

7 POINT SOURCE CRITERIA

Ethylene plant can be considered as point source if plant specific data are available.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

As stated in section 4, an overall VOC emission factor for the ethylene production in the Netherlands is 0.6 ton VOC per kton ethylene produced.

Based on the data presented in section 3.4 and an ethylene percentage of 36 of the product from the typical feed (sections 1, 3.1) the emission factor of VOC for the ethylene production (without taking notice of other products) can be estimated in more detail as follows:

1 0.389 ton VOC/kton ethylene production capacity (leakage and losses)

Namely, 0.36 * 0.73 * 4000 ton VOC per 2700 kton ethylene production capacity for leakages and losses during handling and storage (together 73% of emissions).

2 0.162 ton VOC/kton ethylene produced (combustion, flaring, other processes)

Namely, 0.36 * 0.27 * 4000 ton VOC per 2400 kton ethylene produced

Part of these emissions are already dealt with under other SNAP codes (combustion and flaring): 0.138 ton VOC/kton ethylene produced.

Namely, 0.36 * (0.18 + 0.05) * 4000/2400.

Table 8.1 lists emission factors used in or calculated for different countries.

Table 8.1.: Emission factors for ethylene

Source	Factor (kg/ton)	Quality Code
TNO Emission Registration 1987 [4]	2 (new plant)	C
TNO Emission Registration 1987 [4]	5 (old plant)	C
American report [5]	10[1]	C/D
Environment Canada [3]	0.9, 1.8, 5.1, 8.2	D
Borealis AB [2]	2 - 7	C

[1] with an estimated capacity of 200 kton/y

9 SPECIES PROFILES

Table 9.1 and 9.2 list the VOC profile respectively for the different sources and the overall profile.

Table 9.1: The composition of the VOC emissions for the different sources is [1]:

	methane	ethylene	propylene	benzene	others HC's
leakage loss	70%	5%	3%	1%	21%
flaring and disruptions	10%	40%	25%	1%	24%
storage and handling loss	0%	0%	0%	1%	99%
combustion	75%	10%	0%	1%	14%
other process emissions	70%	5%	3%	1%	21%

Table 9.2: The overall VOC emission profile for ethylene plants

	TNO ER [1]	EPA [6]
methane	58.8%	12.5%
ethane	-	37.8%
ethylene	11.5%	-
propane	-	23.9%
propylene	6.8%	-
n-butane	-	15.0%
n-pentane	-	8.1%
benzene	1.0%	2.1%
toluene	-	0.5%
methanol	-	0.3%
other HC's	22.0%	-

10 UNCERTAINTY ESTIMATES

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

- These data so far assume an average feed and an average composition of the production process in which a wide range of other commodities are produced in addition to ethylene.
- The leakage losses are estimated with emissions factors used for the chemical industry as a whole. No subdivision within the chemical industry is made.
- The flaring emission is based on an assumed combustion percentage. The measurement of the amount of gas flared is inaccurate and in most cases only roughly estimated.

- The emission factors used in Section 8 are derived from ethylene plants in the Netherlands.
- One factor is used for all countries. It would be more accurate to use a different factor for each country or each group of countries.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

National emission estimates can be disaggregated on the basis of production, population or employment statistics.

13 TEMPORAL DISAGGREGATION CRITERIA

The ethylene plants are operated in continuous flow, thus no variation in emissions diurnally or seasonally is expected to occur.

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCEDURES

Verification of the emissions can be done by comparing with measurements in the individual plant or by setting up a mass balance over the entire plant.

17 REFERENCES

1 TNO Emission Registration 1992.
2 Borealis AB, Sweden, personal communication 1995.
3 Emissions of Volatile Organic Compounds from selected organic chemical plants, B.H. Levelton & Associates Ltd., 1990.
4 TNO Emission Registration 1987.
5 American report.
6 EPA, SPECIATE.

18 BIBLIOGRAPHY

- Kirk-Othmer, Encyclopedia of Chemical Technology, Volume 14, 4th Edition (1995).
- Winnacker-Küchler, Chemische Technologie, Organische Technologie I, Band 5, 4. Auflage (1982) (in German).

19 RELEASE VERSION, DATE AND SOURCE

Version: 2.2

Date: October 1995

Source: J. J. M. Berdowski, W. J. Jonker & J. P. J. Bloos
TNO
The Netherlands

20 POINT OF ENQUIRY

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