EXTERNALITY STUDY ON GRESIK COMBINED-CYCLE

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ABSTRACT

EXTERNALITY STUDY ON GRESIK COMBINED-CYCLE. Based on INS/0/016 program concerning IAEA Initial Training On Health And Environment Impacts Of The Different Energy Sources For Electricity Generation in Indonesia Using Simpacts Program, Externality Study of Power Generation Plant is a part of the Comparative Assessment. One of the power generation plants is combined-cycle Plant, and Gresik combined-cycle Plant have been chosen in this study. Those plants are major electricity contributor for eastern part of Java province and a predominant energy source in industrialized area in this province. The objective of this study is to assess the environmental burdens, physical impacts and damage cost to human health resulting from pollutant released into the biosphere, and provide the data requirements as input data for the externality study of combined-cycle plant. The data requirements are average annual wind speed, effective chimney height, specified emission of gas fired plants, receptor density (population density in local area) and meteorology data for Gresik is assumed to be the same as that of Jepara. The estimated externality cost will be considered as an additional cost into society cost. By using the Simpacts module to generate damage cost, result of the externality cost for Gresik combined-cycle is 1.32 mills/kWh. This damage cost dominated by long-term mortality case for adult due to nitrate pollutant (58 %) and followed by chronic bronchitis case for adult due to particulate material pollutant (18 %), long-term mortality case for adult due to particulate material pollutant (9 %) and restricted activity day for adult due to nitrate (6 %). This result will be basically useful for making Comparative Study of Electricity Generation in Indonesia.

ABSTRAK

STUDI EKSTERNALITAS PADA PLTGU GRESIK. Berdasarkan pada program INS/0/016 tentang Pelatihan Pendahuluan IAEA mengenai Dampak Kesehatan dan Lingkungan dari Berbagai Sumber Energi Untuk Pembangkitan Listrik di Indonengan dengan menggunakan Program Komputer *Simpacts*, Studi Eksternalitas Pembangkit Tenaga Listrik merupakan salah satu bagian dari Pengkajian Komparatif. Salah satu Pembangkit Listrik yang menjadi perhatian adalah Pembangkit Siklus Ganda (Combined-Cycle, PLTGU), dan PLTGU Gresik merupakan pilihan dari studi ini. Seluruh pembangkit listriknya merupakan kontributor listirk terbesar untuk wilayah propinsi Jawa Timur dan sebagai sumber energi utama untuk kawasan industri di daerah ini. Tujuan dari studi ini adalah untuk mengkaji beban lingkungan, dampak fisik dan biaya kerusakan terhadap kesehatan manusia akibat dari polutan yang terlepas ke biosfir, serta menyajikan persyaratan data untuk data masukan pada studi eksternalitas PLTGU. Data yang dibutuhkan adalah kecepatan angin rerata tahunan, tinggi efektif cerobong, emisi spesifik PLTGU, kepadatan reseptor (kepadatan penduduk lokal) dan data meteorologi untuk daerah Gresik diasumsikan memiliki pola yang sama dengan daerah Jepara. Biaya eksternalitas yang terkira akan dianggap sebagai biaya tambahan ke dalam biaya sosial masyarakat. Dengan menggunakan Modul Simpacts untuk menghitung biaya kerusakan, hasil biaya eksternalitas yang diperoleh untuk PLTGU Gresik adalah 1,32 mills/kWh. Biaya kerusakan didominasi oleh kasus mortalitas jangka-panjang pada orang dewasa akibat polutan nitrat (58 %) dan diikuti oleh kasus *bronchitis* kronik pada orang dewasa akibat polutan partikel (18 %), kasus mortalitas jangka-panjang pada orang dewasa akibat polutan partikel dan gangguan kegiatan harian pada orang dewasa akibat polutan nitrat (6 %). Hasil ini akan bermanfaat untuk melakukan Studi Komparatif Pembangkit Listrik di Indonesia.

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*) *Bidang Sistem Energi P2EN - BATAN*

I. INTRODUCTION

I.1. Background

Since the onset of the industrial revolution in 19th century, production and the accumulation of wealth in the industrialized North has been essentially driven by the increasing use of fossil fuel. Between 1960 and 1997, global energy use increased about three fold. For electricity, the consumption of electricity increased more than five fold over the 1960 to 1997. Fraction of electricity generation increased from 17 % to 27 %. The standard of living and level of economic development can be measured as income per capita and can be indicated by energy and electricity use per capita. Recently, commercial energy and electricity consumption in developing countries are about 0.6 ton of oil equivalent per capita (toe/cap) and 800 kilowatt hours per capita (kWh/cap), corresponding to about one-ninth of those in the Organization for Economic Cooperation and Development (OECD) countries and one-twelfth of those in North America. However, some two billion people living in developing countries do not yet have access to modern, commercial energy services, especially those provided by electricity. Environment burdens in the developing countries are primarily local and regional. These burdens will be more severe and more damaging. In addition, because of the short-term economics in developing countries the transition from unsustainable non-commercial energy to commercial energy supply tend to use low cost fossil technologies (predominantly coal) with little or no pollution abatement.

Considering the global impacts, a rational policy for the regulation of the environment is needed to balance the costs of achieving a lower level of environmental and health damage against the benefits of providing electricity at reasonable cost. This task become much easier, if the comparison of the cost and the impacts can be made in monetary terms.

Based on INS/0/016 program concerning "*IAEA Initial Training On Health And Environment Impacts Of The Different Energy Sources For Electricity Generation In Indonesia Using Simpacts Program*". The externality study of power generation plant become a part of the Comparative Assessment. One of the power generation plants is combined-cycle Plant, and Gresik combined-cycle plants have been chosen in this study. Those plants are a major electricity contributors for eastern part of Java province and a predominant energy source in industrialized area in this province.

I.2. Objective

The objective of this study is to assess the environmental burdens and physical impacts and damage costs to human health resulting from pollutant released into the biosphere, and provide the data requirements as input data for the externality study of COMBINED-CYCLE plant. The data requirements are such as: average annual wind speed, effective chimney height, specified emission of gas fired plants, receptor density (population density in local area), etc. The predicted external cost will be considered as an additional cost into society cost.

II. METHODOLOGY

The methodology is taken from Simpacts module[1], as follows:

- Identify and calculate power generation emission source (source characterization).
- Calculate dispersion of pollutants to the area.
- Determine of dose
- Calculate the damage cost

III. GEOGRAPHY

III.1. Brief of Indonesia

Indonesia is the largest archipelago in the world with the total number of 17,508 islands according to the Indonesian Naval Hydro-Oceanographic office.[7] The archipelago is on a crossroads between two oceans, the Pacific and the Indian ocean, and bridges two continents, Asia and Australia.

The territory of the Republic of Indonesia stretches from 6°08' north latitude to 11°15' south latitude, and from 94°45' to 141°05' east longitude. The Indonesian sea area is four times greater than its land area. The sea area is about 7.9 million sq. km (including an exclusive economic zone) and constitutes about 81% of the total area of the country.

The five main islands are: Sumatra, which is about 473,606 sq. km; the most fertile and densely populated islands, Java and Madura, about 132,107 sq. km; Kalimantan, about 539.460 sq. km; Sulawesi, about 189,216 sq. km; and Irian Jaya, about 421.981 sq. km. Indonesia's other islands are smaller.

Climate And Weather

The climate and weather of Indonesia is characterized by two tropical seasons, which vary with the equatorial air circulation (*the Walker circulation*) and the meridian air circulation (*the Hardley circulation*). The displacement of the latter follows the north-south movement of the sun and its relative position from the earth, in particular from the continents of Asia and Australia, at certain periods of the year.

The climate changes every six months. The dry season (June to September) is influenced by the Australian continental air masses; while the rainy season (December to March) is the result of the Asian and Pacific Ocean air masses. The transitional periods between the two seasons are April to May and October to November.

Temperature and Humidity

Due to the large number of islands and mountains in the country, average temperatures may be classified as follows: coastal plains: 28°C inland and mountain areas: 26°C higher mountain areas: 23"C, varying with the altitude. Being in a tropical zone, Indonesia has an average relative humidity between 70% and 90%, with a minimum of 73% and a maximum of 87%.

People

Indonesian Government on population policy is directed toward development of the population as human resources in order that the national development can be effective and valuable, while the quality of life is gradually improving. Meanwhile, control of population growth is carried out through efforts to lower the birth and mortality rate, especially that of infants and children. These efforts in particular have been implemented through family planning programs which also have the purpose of improving the welfare of mother and child and at the same time create a small, happy, and prosperous family.

The implementation of population policy has noted significant progress. In 1998, the life expectancy was 64.7 years, the crude death rate was 7.7 per 1,000 people, and the infant mortality rate was 50 per 1,000 live birth. Meanwhile the crude birth rate in 1998 was 22.7 per 1,000 people and the total fertility rate was 2,59 per woman. Until June 1999, the total population is approximately 209 millions.

III.2. Brief of East Java Province

Figure 1. Map of Indonesia and East Java Province

The capital and gateway of East Java is Surabaya. The hub of the province's economic and commercial life, Surabaya has its industrial center at Rungkut, in the south of the city. In this area, various industries from shipbuilding to the manufacture of simple tools are concentrated.

The areas of Gresik and Sidoarjo are formally parts of the region of Surabaya. The two townships are at present the center of the province's marine-based economy and of its petrochemical and cement industries, respectively. The regency of Sidoarjo is known for its seafood's and sea products, such as shrimp and shrimp pastes.

The number of East Java population on 1989 was 29.188.852 people, but on 1999 had been increased to 35.16 million people with the density level average was 725 people/ km2 [4].

Wind direction and speed

The wind directions are different depending on time, frequencies of East-wind defined as (NE-SE-SW) and West-wind defined as (SW-NW-NE), which coincide with dry and rainy seasons, respectively. The frequency of East-wind is about twice the frequency of West-wind.

Temperature

Based on the classification of Schmidt and Ferguson system, a part of big area (52%) of East Java has climate type D. Maximum situation of average maximum temperature reach 33 centigrade, but average minimum temperature reach 22 centigrade.

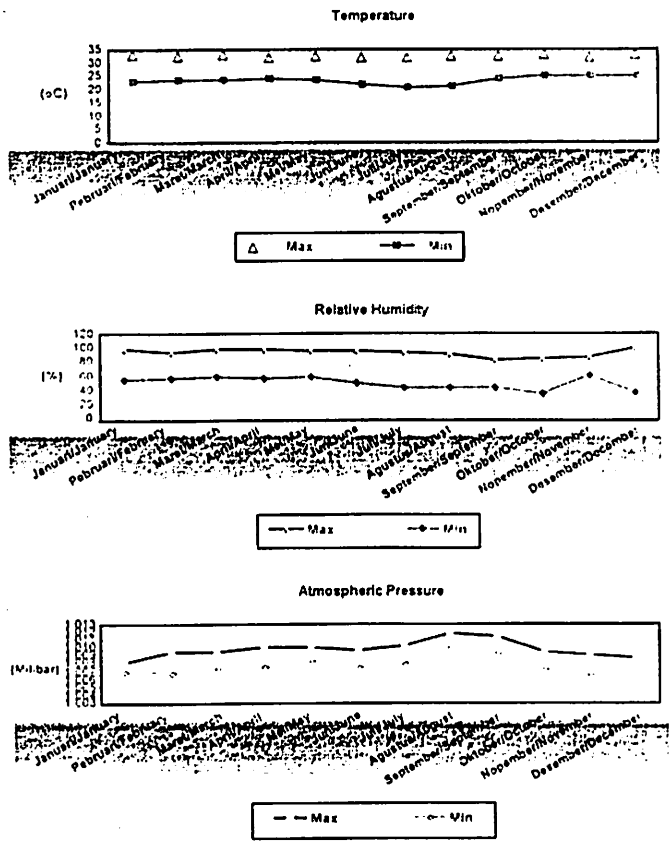

Figure 2. Monthly Weather Condition[4]

III.3. Brief of Gresik Regency

The area of Gresik regency is geographically located between 112 degrees and 113 degrees east longitude and between 7 degrees and 8 degrees south latitude, and it is bordered on:

- the north: by Java Sea
- the east : by the straits of Madura and Surabaya municipality
- the south: by Sidoarjo regency
- the west : by Lamongan regency

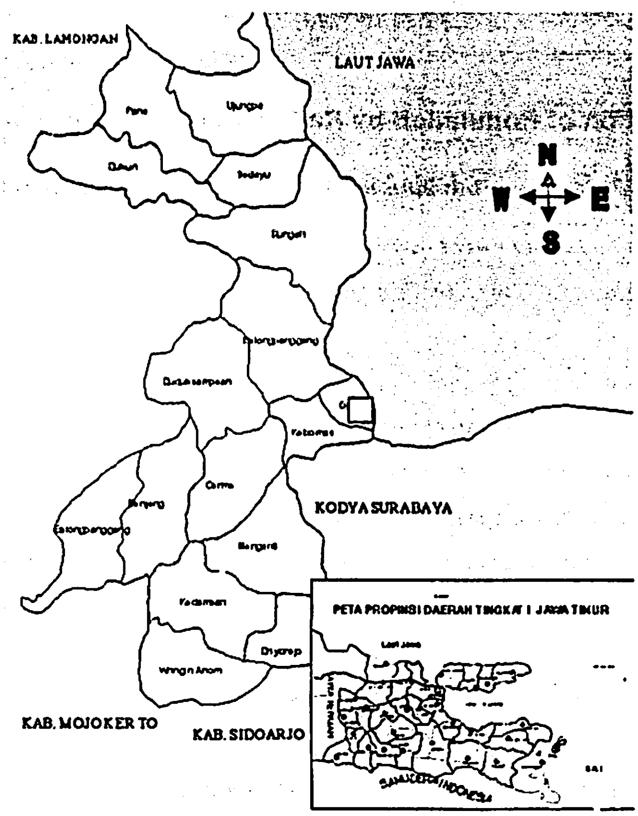

Figure 3. Map of Gresik Regency [3]

Gresik regency covers the land area of Gresik itself and the isle of Bawean extending at 1,173.69 sq. km or 1,173 Ha. It comprises total land area of Gresik at 984.94 sq. km and total land area of Bawean isle at 188.75 sq. km. This region administratively consists of: [3]

- District (Assistance to Regent) : 5 areas
- Sub-district : 18 areas
- Kelurahan (village in urban region): 26 areas
- Desa (village in rural region): 331 areas

DATA INPUT

IV.1. Distribution of Population by Radius [based on ref. 3, 4]

Table 1. Estimated Population around Gresik Station in 5 x 5 km2 cell

	-47.5	-42.4	-37.5	-32.5	-27.5	-22.5	-17.5	-12.5	-7.5	-2.5	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5
-47.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-42.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-37.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-32.5	7188	8985	10782	10782	8985	9190	950	5699	5699	0	0	0	0	0	0	1513	2269	2269	2269	1450
-27.5	17970	17970	17970	17970	17970	18688	17096	15197	15197	0	0	0	0	1513	12857	15125	15125	14369	15125	13773
-22.5	17358	17970	17970	17970	18432	18893	18996	18996	17096	4749	0	0	756	9832	15125	15125	15125	15125	15125	14498
-17.5	17153	17970	17970	17970	18227	18432	18740	18996	18996	16147	0	1513	9075	15125	15125	15125	15125	15125	15125	14498
-12.5	16949	17970	17970	17970	17970	17970	17970	18432	18996	18996	1156	13613	15125	15125	15125	15125	15125	15125	15125	14498
-7.5	17766	17970	17970	17970	17970	17970	18073	18432	18996	8319	5294	15125	15125	15125	15125	15125	15125	15125	15125	15000
-2.5	17970	17970	17970	17970	17970	17970	18842	18996	18996	12347	4538	14369	15125	15125	15125	15125	15125	15125	15125	14812
2.5	17970	17970	17970	17970	17970	18022	18688	18996	18996	44240	2849	32631	30363	2269	5294	7563	12857	15125	14937	13804
7.5	17970	17970	17970	17970	17970	18586	18996	18996	35826	153632	131104	159198	159198	18729	0	0	0	3025	6650	8699
12.5	17970	17970	17970	17970	18124	18996	18996	18996	18996	77899	170462	18791	187291	56187	0	0	0	0	0	0
17.5	17970	17970	17970	18663	23021	22842	18996	18996	18996	18996	136803	187291	187291	74917	0	0	0	0	0	0
22.5	24598	24598	25924	29621	49921	31816	21560	18996	20542	86314	72756	104869	118606	59303	0	0	0	0	0	0
27.5	31226	31226	31226	31639	31816	31816	31816	34459	46829	49921	49921	49921	49921	24961	0	0	0	0	0	0
32.5	31226	31226	31226	31403	41651	51604	39058	49016	49921	49921	49921	49921	47425	19968	0	0	0	0	0	0
37.5	31226	31226	31226	31285	36733	41710	31816	33626	42670	49016	49921	49921	44929	24961	0	0	0	0	0	0
42.5	31226	31226	31226	31374	31816	31816	31816	31816	31816	40868	46415	48752	49921	39937	7488	0	0	0	0	0
47.5	31226	31226	31226	31344	31816	31816	31816	31816	31816	31026	26549	31224	34729	22408	6637	0	0	0	0	0

IV.2. Meteorology

Input data used in this case is assumed to be the same that of Jepara, which has characteristics as follow, [6]

Mean Air Temperature (K):	301.6
Mean Local Wind Speed (m/s):	5.4
Anemometer Height (m):	40
Pasquill Distribution Class A (%):	0.6
Pasquill Distribution Class B (%):	3.9
Pasquill Distribution Class C (%):	8.3
Pasquill Distribution Class D (%):	58.6
Pasquill Distribution Class E (%):	16.4
Pasquill Distribution Class F (%):	12.2
Mean mixing layer height (m):	528.1

IV.3. Gresik Combined-Cycle

Gresik combined-cycle is geographically located in 112.7 degrees east longitude and 7.3 degrees south latitude. Some technical data and gas emission of the plant can be seen in Table 2 and 3, as follows:

Table 2. Some Technical Data of Gresik Combined-Cycle[5]

Unit of Combined-Cycle	Size (MWe)	Chimney		Operation Year
		Diameter Upper (m)	Height (m)	
Block 1	526	5.7	65	10 April 1993
Block 2	526	5.7	65	05 August 1998
Block 3	526	5.7	65	30 September 1993

Table 3. Gas Emission (ton in year 2000)[5]

Unit	Electricity (kWh)	Gas Emision (ton), Average Temperature			
		CO_2	SO_2	NO_x	Dust
GT 1		667 383.97	0	2 329.78	58.24
GT 2		654 856.01	0	2 286.04	57.15
GT 3		608 058.22	0	2 122.68	53.07
BLOCK 1	3.13 E+9	**1 930 298.21**		**6 738.50**	**168.46**
GT 4		630 993.22	0	2 202.74	55.07
GT 5		632 771,95	0	2 208.95	55.22
GT 6		637 558.14	0	2 225.66	55.64
BLOCK 2	3.05 E+9	**1 901 323.32**		**6 637.35**	**165.93**
GT 7		696 248.05	0	2 430.54	60.76
GT 8		732 029.78	0	2 524.03	63.10
GT 9		710 716.32	0	2 481.05	62.03
BLOCK 3	3.50 E+9	**2 129 994.14**		**7 435.62**	**185.89**
TOTAL	**9.66E+09**	**5 961 615.67**	0	**20 811.47**	**520.28**

IV.4. Human Health Endpoint Parameters

Exposure Response Function (ERF) listed in Table 4 for some pollutants will be used for damage cost calculation in this case. The primary pollutant depletion velocities are 1.2 cm/s for PM10 and 1.5 cm/s for NO2; and the secondary pollutant depletion velocity for nitrate is 1.4 cm/s.

The monetary unit costs for the different health endpoints are summarized in Table 4. Approximation estimates for damage calculation based on a number of US.$ 2407 for the Power Purchase Parity (PPP) Gross Domestic Product (GDP) of Indonesia and US.$ 20269 PPP GDP for the European Community with the Income Elasticity Factor is one[1]. Human Health Endpoint Parameters considered consist of 2 (two) parameters, namely:

- Exposure Response Function Slope in [cases/(yr.person.μg/m^3)]
- Monetary Unit Costs in [US$/case]

Table 4. Exposure Response Function Slope in [case/(yr. Person. μ g/m^3)] and Monetary Unit Costs in US.$/case. [1,2]

Exposure Response Function	Pollutant	ERF Slope	Type of Impact	Unit Cost
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates]	Nitrates	2.60E-04	Long-term mortality	1.1994E+04
Restricted Activity Days - Recommended; Adults over 18; Nitrates	Nitrates	2.20E-02	Morbidity	1.3780E+01
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates]	Nitrates	9.73E-02	Morbidity	9.5000E-01
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates]	Nitrates	4.10E-02	Morbidity	9.5000E-01
Respiratory Hospital Admissions - Recommended; ALL; Nitrates]	Nitrates	2.56E-06	Morbidity	5.3914E+02
Chronic Bronchitis - Recommended; Adults over 18; Nitrates	Nitrates	4.48E-05	Morbidity	2.1114E+04
Respiratory Hospital Admissions; ALL; NO2	NO2	1.56E-06	Morbidity	5.3914E+02
Short-term Mortality (YOLL); ALL; NO2	NO2	1.70E-06	Short-term mortality	2.0663E+04
Restricted Activity Days - Recommended; Adults over 18; PM10	PM10	2.20E-02	Morbidity	1.3780E+01
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10	PM10	2.60E-04	Long-term mortality	1.1994E+04
Respiratory Hospital Admissions - Recommended; ALL; PM10	PM10	2.56E-06	Morbidity	5.3914E+02
Chronic Bronchitis - Recommended; Adults over 18; PM10	PM10	4.51E-05	Morbidity	2.1114E+04
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10	PM10	9.62E-02	Morbidity	9.5000E-01
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10	PM10	4.10E-02	Morbidity	9.5000E-01
Short-term Mortality (YOLL) - Recommended; ALL; SO2	SO2	2.30E-06	Short-term mortality	2.0663E+04
Respiratory Hospital Admissions - Recommended; ALL; SO2	SO2	2.84E-06	Morbidity	5.3914E+02
Chronic Bronchitis - Recommended; Adults over 18; Sulfates	Sulfates	1.26E-04	Morbidity	2.1114E+04
Restricted Activity Days - Recommended; Adults over 18; Sulfates	Sulfates	8.23E-02	Morbidity	1.3775E+01

V. RESULTS AND ANALYSIS

Basically, pollutants emitted from power plant can be called as primary pollutant, namely particulate matter (PM10), Sulfur Dioxide (SO_2), Nitrogen Oxide (NO_x) and Carbon Mono-oxide (CO). Later, these pollutants will produce Nitrate and Sulfur aerosol, which called as secondary pollutants. [1]

Results of QUERY module running could be classified in two considerations such as number of impacts and damage costs.

V.1. Impacts (number of cases)

Exposure Response Function	Pollutant	Block 1	Block 2	Block 3	TOTAL
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates	Nitrates	1.98E+02	1.95E+02	2.19E+02	6 13E+02
Restricted Activity Days - Recommended; Adults over 18; Nitrates	Nitrates	1.68E+04	1.65E+04	1.85E+04	5 19E+04
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates	Nitrates	7.43E+04	7 32E+04	8.20E+04	2 29E+05
Lower Resp. Symptoms - Recommended; Asthmatic Children, Nitrates	Nitrates	3.13E+04	3 08E+04	3 45E+04	9 66E+04
Respiratory Hospital Admissions - Recommended; ALL; Nitrates	Nitrates	1 95E+00	1.92E+00	2.16E+00	6 03E+00
Chronic Bronchitis - Recommended; Adults over 18; Nitrates	Nitrates	3.42E+01	3.37E+01	3.78E+01	1 06E+02
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	6 92E+00	6.82E+00	7.64E+00	2.14E+01
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	7.51E+00	7.40E+00	8.29E+00	2.32E+01
Restricted Activity Days - Recommended; Adults over 18; PM10	PM10	2.54E+03	2.50E+03	2.80E+03	7 83E+03
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10	PM10	3.00E+01	2.95E+01	3.31E+01	9 26E+01
Respiratory Hospital Admissions - Recommended; ALL; PM10	PM10	2.95E-01	2.91E-01	3.26E-01	9.11E-01
Chronic Bronchitis - Recommended; Adults over 18; PM10	PM10	5.20E+00	5.12E+00	5.74E+00	1 61E+01
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10	PM10	1.11E+04	1.09E+04	1.22E+04	3 42E+04
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10	PM10	4.73E+03	4.66E+03	5.22E+03	1 46E+04
Total		1.41E+05	1.39E+05	1.56E+05	4.35E+05

a. *Impacts for each health endpoint.*

Impact resulted from Block 3 has the highest number of cases, 0.156 million cases and total impact from whole block of Gresik Plant is 0.435 million cases, which dominated by case of lower respiratory symptoms for asthmatic adult to nitrate pollutant (0.229 million cases). For other impacts could be seen in Figure 4.

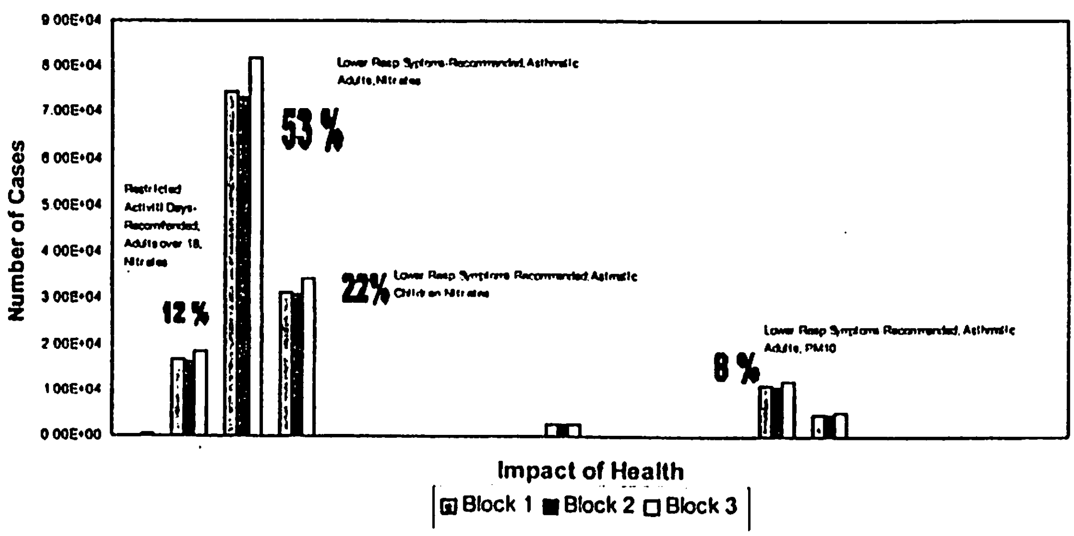

Figure 4. Number of Cases for Each Health Point

b. *Impacts by type of pollutant*

The impact of Cases is mostly due to Nitrate and PM10. Nitrates contribute about 0.13 million cases per block of plant and PM10 is only 15 thousand cases per block of plant. These Impacts can be shown in Figure 5.

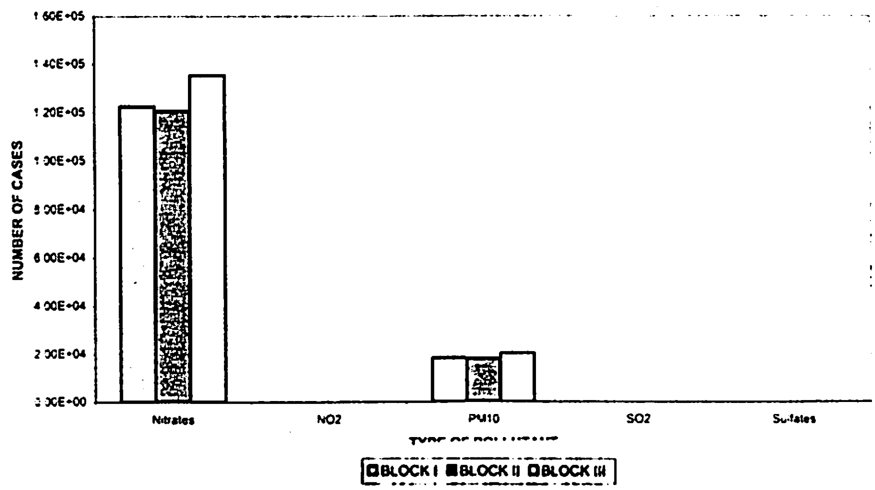

Figure 5. Number of Cases for Type of Pollutant

V.2. Damage Cost

Exposure Response Function	Pollutant	Block 1	Block 2	Block 3	Total
Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates	Nitrates	2.38E+06	2.34E+06	2.63E+06	7.35E+06
Restricted Activity Days - Recommended; Adults over 18; Nitrates	Nitrates	2.31E+05	2.28E+05	2.55E+05	7.15E+05
Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates	Nitrates	7.06E+04	6.95E+04	7.79E+04	2.18E+05
Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates	Nitrates	2.97E+04	2.93E+04	3.28E+04	9.18E+04
Respiratory Hospital Admissions - Recommended; ALL; Nitrates	Nitrates	1.05E+03	1.04E+03	1.16E+03	3.25E+03
Chronic Bronchitis - Recommended; Adults over 18; Nitrates	Nitrates	7.22E+05	7.12E+05	7.97E+05	2.23E+06
Respiratory Hospital Admissions; ALL; NO2 [Ponce de Leon, 1996]	NO2	3.73E+03	3.68E+03	4.12E+03	1.15E+04
Short-term Mortality (YOLL); ALL; NO2 [APHEA, 1997]	NO2	1.55E+05	1.53E+05	1.71E+05	4.79E+05
Restricted Activity Days - Recommended; Adults over 18; PM10	PM10	3.49E+04	3.44E+04	3.86E+04	1.08E+05
Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10	PM10	3.60E+05	3.54E+05	3.97E+05	1.11E+06
Respiratory Hospital Admissions - Recommended; ALL; PM10	PM10	1.59E+02	1.57E+02	1.76E+02	4.91E+02
Chronic Bronchitis - Recommended; Adults over 18; PM10	PM10	1.10E+06	1.08E+06	1.21E+06	3.39E+06
Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10	PM10	1.06E+04	1.04E+04	1.16E+04	3.28E+04
Lower Resp. Symptoms - Recommended; Asthmatic Children; PM10	PM10	4.49E+03	4.42E+03	4.96E+03	1.39E+04
Total of Damage Cost in US $		4.11E+06	4.05E+06	4.54E+06	1.27E+07
Electricity in kWh		3.13E+09	3.03E+09	3.50E+09	9.66E+09
Externality Cost in mills/kWh		1.31	1.34	1.30	1.32

a. Damage cost for each health endpoint

Total damage cost that should be paid by utility of Gresik is about 12.7 million US.$ per year (in this case in 2000) and about 4.23 million US.$ per year per block of plant. This cost is named society cost. In term of externality cost, total damage cost divided by electricity produced, Gresik Combine Cycle Plant has a value of 1.32 mills per kWh.

Total damage cost of health which is dominated by case of long-term mortality for adult due to nitrate, is about 7.35 million US.$ per year with 58 % of total damage cost, and followed by case of chronic bronchitis for adult due to nitrate, case of long-term mortality for adult due to PM10 and case of restricted activities days for adult due to nitrate, etc. The damage cost for each health endpoint can be seen in Figure 6.

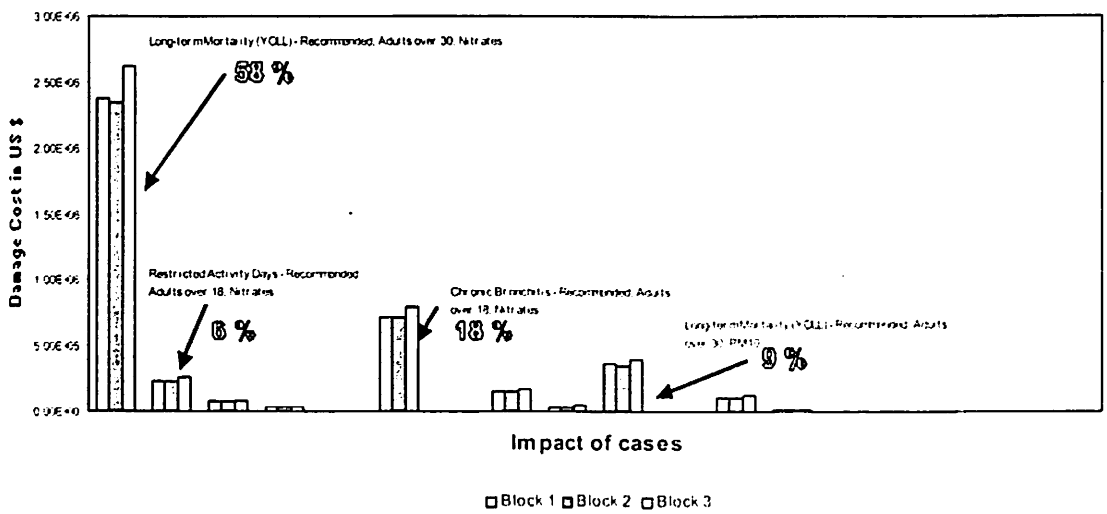

Figure 6. Damage cost for each health endpoint

b. Damage cost by type of pollutant

Damage cost expensed by utility of Gresik due to emission is dominated by nitrate, PM10 and NO2. Nitrate contribute about 10.6 million US.$ per year, PM10 is about 1.6 million US.$ per year and NO2 is about 0.491 million US.$ per year. For each block can be seen in Figure 7.

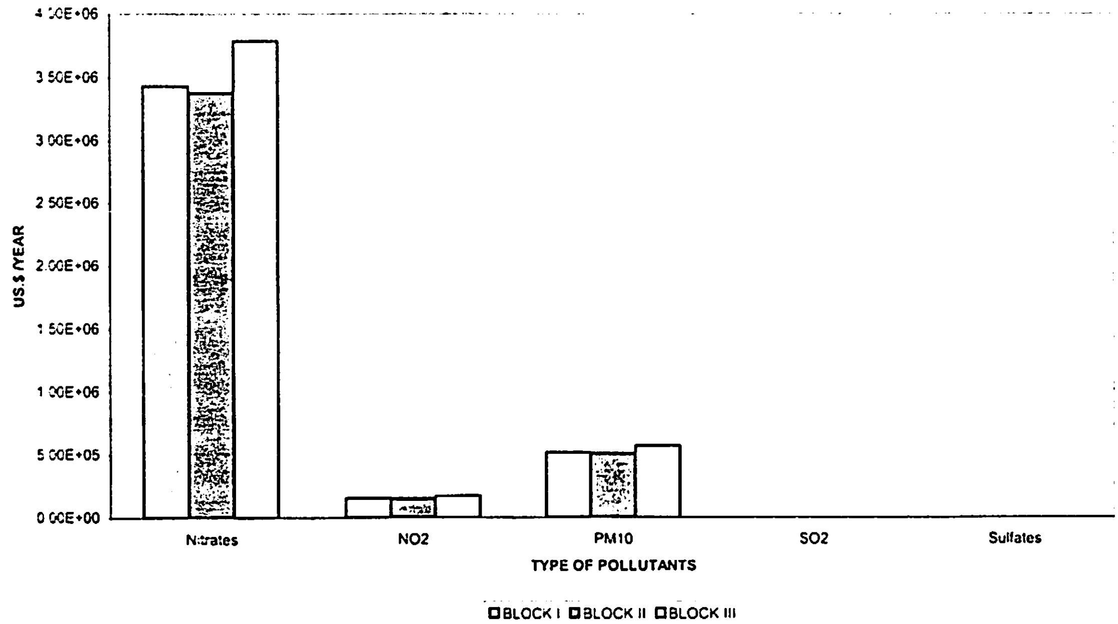

Figure 7. Damage Cost for Each Pollutan in US.$

In term of damage cost per kg pollutant, PM10 has the most expensive with 3.032 US.$ per kilogram and followed by nitrate about 0.5098 US.$ per kilogram, these values can seen in Figure 8.

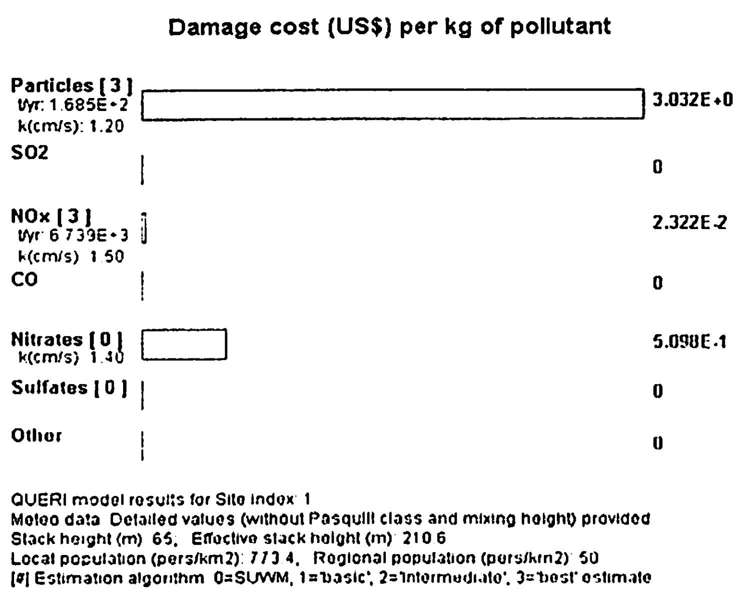

Figure 8. Damage Cost per kg for Each Pollutant

VI. CONCLUSION

1. The impact of pollutant case per year (in year 2000) is dominated by Lower Resp. Symptoms - Recommended; Asthmatic Adults; Nitrates of 53 %, Lower Resp. Symptoms - Recommended; Asthmatic Children; Nitrates of 22 %, Restricted Activity Days - Recommended; Adults over 18; Nitrates of 12 %, Lower Resp. Symptoms - Recommended; Asthmatic Adults; PM10 of 8 %.

2. The damage cost is domated by Long-term Mortality (YOLL) - Recommended; Adults over 30; Nitrates of 58 %, Chronic Bronchitis - Recommended; Adults over 18; PM10 of 18 %, Long-term Mortality (YOLL) - Recommended; Adults over 30; PM10 of 9 %, Restricted Activity Days - Recommended; Adults over 18; Nitrates of 6 %.

3. The average of externality cost for Gresik Gas Combine Cycle is 1.32 mill/kWH.

VII. REFERENCES

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