Maritime Engineering and Ports II, C.A. Brebbia & J. Olivella (Editors)

Environmental impact of port activities

C. Trozzi, R. Vaccaro
Techne srl, Via N. Zabaglia 3, 00153 Rome (Italy)

Abstract

In the last years the growing environmental and sanitary impact of road transport and the connected growing costs has gave new impulse to ship transport. Ships activities grow, while reduce the global impact of transport, cause new environmental problems in port areas.

In the paper the need for a global approach to port environment in the frame of sustainable development was introduced.

The sources of pollution from ships, from port activity other than ships and from industrial activities in port areas with reference to air, water, soil, waste and noise are analyzed. Diffusion and/or propagation models are reviewed. Finally, technologies for reducing environmental impact are analyzed.

Introduction

The establishment of a balance between economical and ecological interests will be the most important issue for the next decade for all modes of transport, including waterborne transport.

Any kind of economic and industrial activity has a certain impact on nature. It should be therefore be our aim to minimize the adverse impact, this being even more important when new activities are under planning. In ports we encounter negative environmental impact by emissions of noise, odors, volatile organic substances, and pollution of water and soil by oil chemicals, hull paint and other hazardous material [1].

In the paper a complete review of the environmental issues in ports and of the tools to assess and minimize such negative environmental impact are analyzed.

Integrated emission inventory approach in port areas

The environmental characterization of port areas can be performed using the methodologies of integrated emission inventories [2] based on sources common nomenclature [3].

The preparation of integrated emissions inventories, in port areas, allows to characterize the different role played by the various emission sources, in the different environmental media, and consequently represents a basic tool to define criteria for environmental quality management.

For the realization of emissions inventories several methodologies are available (by OCSE [4] and, for air pollution, by EMEP/CORINAIR Task Force on Emission Inventories [5], United States Environmental Protection Agency [6] and Netherlands Ministry of health and environmental protection [7,8]).

The sources are generally splitted in three categories: point sources (the main industrial and commercial sources), linear sources (the main transport network) and distributed sources (all the other sources).

For the realization of inventories from point sources it is useful to take into account the pollutant release and transfer registers [9, 10]. From this documentation it is possible to roughly evaluate the emissions for industrial points sources.

Traffic census data and emission factors, or more complex models, are used to estimate pollutants emissions from linear sources (road, river, railway, seaway).

Regarding distributed sources a statistical treatment of information is necessary. These sources are evaluated on a geographical basis, inside each district or area and subsequently spatially disaggregated in thinner meshes. Distributed sources are characterized collecting data on suitable activity indicators (paint consumption, fuel consumption, etc.) using statistics and ad hoc inquiries and suitable emission factors (in mass for activity inidcators units) from literature or local data.

Finally emissions estimate in special fields (road traffic, airport, vegetation, forest fires) can be evaluated by using specialized models [11].

Sources of emissions from ships

Pollution of air

All ships activities are responsible of air pollutants emissions and particularly: ships movement in port, ships activities in hotelling phase (lighting, heating, refrigeration, ventilation, etc.), tanker loading and unloading.

A suitable methodology for the estimate of air pollutant emissions from ships, in port environment and in navigation, has been developed in the framework of MEET Project (Methodologies for estimating air pollutant emissions from transport) under the transport RTD program of the European Commission fourth framework program [12]. The methodology has been previous reviewed in two specialty conferences on marine combustion engines [13] and ports [14] and in the conference on EC COST action [15].

The model summarize shipping activity in one cruising phase, two maneuvering phases (the first one starts when the ship's deceleration begins and ends at the docking, the second one starts with departure from the berth and ends when cruising speed has been reached), and one hotelling phase (at dockside power must be generated in order to supply the ship's lighting, heating, refrigeration, ventilation, etc.). For liquid bulk ships power requirements of the cargo pumps for tanker off-loading and of the ballast pumps for tanker loading must be also take into account. The emission factors and specific fuel consumption can be found in cited literature [12].

Pollution of water

In port and in its neighborhood there are different sources of water pollution from ships:

- oil of bilge and motor fuel leakage from ships and gasoline and diesel oil leakage from pleasure crafts;
- accidental leakage of oil and chemical substances in loading and unloading of products;
- pollution from slop (residual of chemical products contained in the tanks and of the product used in the washing operations) either in the case in which it is treated and in the case in which it is unauthorized discharged (tanks washing close to the coast);
- leaching of antifouling paints (particularly containing organotin tributyltin) used to coat the bottoms of ships to prevent sealife such as algae and mollusks attaching themselves to the hull - thereby slowing down the ship and increasing fuel consumption;
- transfer of harmful aquatic organisms (including dormant stages of microscopic toxic aquatic organisms such as dinoflagellates, pathogens such as the bacterium *vibrio cholerae*) with ballast water, used to stabilize vessels at sea (globally, IMO estimates that about 10 billion tons of ballast water is transferred each year); as ships travel faster and faster, the survival rates of species carried in ballast tanks have increased; as a result, many introductions of non-indigenous organisms in new locations have occurred, often with disastrous consequences for the local ecosystem - which may include important fish stocks or rare species.

While in air pollution evaluation there are a lot of suitable emission factors, there is no detailed information on emissions in water.

Wastes production

During ships operation a number of waste products are generated onboard the ship. Depending on trade and area the ship is operating in, the ship must collect the waste to be discharged ashore at ships call. The IMO, annexes I - V, regulations give guidance for most of the main products that is to be discharged and not dumped at sea. Ship generation of waste can not easily be measured in the ports. Due to the rules, regulations and cost of discharging waste in the port some information will not be correct by collecting information from ports only as the ship try to save the waste and discharge it where it gives the lowest cost. A

recently concluded project under the transport RTD program of the European Commission fourth framework program [16] gives suitable waste production factors for oily waste, sewage and garbage for different ship types.

Noise generation

The major noise sources in a ship are the main propulsion machinery, the auxiliary engines, the propeller and transverse propulsion unit, and the heating, ventilation and air conditioning system [17, 18].

The majority of main and auxiliary machinery is driven either by diesel engines or steam turbines. These last generate less noise than diesel engines with similar output power.

Machinery generates noise into the surrounding air and also induces vibration into any structure to which it is connected. Noise transmission can either be waterborne, airborne or structureborne. The most important noise for the port area is the airborne noise and particularly the ambient noise in outdoor areas.

Sources of emissions from port activities (other than ships)

Pollution of air

In port environment there are a lot of activity connected with ships activities, generating air pollution, and in particular:

- loading and unloading of petroleum products produce volatile organic compound emissions;
- dry docks (evaporative volatile organic compound emissions);
- passenger car traffic (combustion products and evaporative volatile organic compound emissions);
- heavy vehicle traffic (combustion products emission);
- railway traffic (combustion products emission);
- demolition or main modification of ships (asbestos, heavy metals, hydrocarbons, ozone depleting substances and others).

Pollution of water

In port and in its neighborhood there are different sources of water pollution:

- operations on terminals and fuel deposits (accidental discharge of oil in the sea, loss from deposit tankers and pipeline);
- dry docks operations (accidental discharge of oil and other chemicals in the sea);
- ships demolition (accidental discharge of oil and other chemicals in the sea);
- storm water runoff from port parking lots (organic compounds, fine particulate, heavy metals, ecc.);
- water thermal pollution;
- water stagnation and eutrophication and anoxia risks due to weak water turnover;

- dredging and escavation of port areas with resuspending of materials and pollutants.

Pollution of soil

In port and in its neighborhood there are different sources of soil pollution:

- operations on terminals and fuel deposits (accidental discharge of oil in the soil, loss from deposit tankers and pipeline);
- spill from the bulk handling device (oil, rubber etc.) and dust spread during the handling (transports between quay and storage area);
- oil and other spillage from the vehicles dissolve the surface and may cause a homogeneous tarmac to dissolve; heat and high loads cause settlements of the surface;
- spill of chemicals from demolition of ships (see the next paragraph).

Wastes production

The following main sources of wastes can be recognized in port and in its neighborhood:

- oil terminals and fuel deposits (oily and toxic sludges);
- dry docks operations (oily and toxic sludges);
- ships demolition (particularly in India, Bangladesh, Pakistan and in the future probably, China, Vietnam and Philippines) connected with the nearly complete absence of facilities for handling waste residues from the demolition process (including heavy metals, PCB, HFC's, asbestos as well as hydrocarbons) [19];
- maintenance and retrofits of older vessels, also in developed countries.

Noise generation

Sources of noise can be individuated in port areas in the following three main areas:

- passenger car and heavy vehicle (trucks) road traffic (the most important one);
- goods movement (from machinery such as quay-crane, pumps, etc.);
- rail traffic noise: rail movement in port and in surrounding areas are prevalent to low speed and of consequence the noise level is not so high, however in highly trafficked areas the problem can be relevant.

Sources of emissions from industrial activities in port

The development of ports is always linked to industrial activities in order to benefit of the proximity of loading and unloading vessels and to avoid costly load breakdowns. Industrial activities are generally heavy activities such as power plants, ships building plants, iron and steel plants, non-ferrous metal industry, paper and paper pulp plants, oil refineries, chemical and petrochemical plants, airports. All the industrial activities in ports have a high potential of air,

Maritime Engineering and Ports II, C.A. Brebbia & J. Olivella (Editors)

water, soil pollution and wastes and noise generation. All the sources must be evaluated in the frame of integrated emission inventory approach.

Pollutants diffusion evaluation

Pollution of air

Air diffusion models are available for the study of coastal area [20], for classical industrial sites studies [21], and for the study of photochemical pollution [22, 23, and 24].

Pollution of water

There are a lot of models suitable for the quantification of the phenomena of diffusion and transport of the pollutants in relation to the hydrodynamic characteristics of sea currents and wind. For example, the US EPA WASP4 Model is a flexible tool for analysis of a wide variety of pollutants, in almost any type of water body [25].

Pollution of soil

Screening models (such as the US EPA Exposure Model for Soil Organic Fate and Transport – EMSOFT [25]) can be used to assess:

- the mass flux over time of organic chemicals due to the volatilization from contaminated soils to atmosphere;
- chemical concentrations in superficial soil layers over time.

Noise

Some models are available to calculate airborne and structureborne noise generated from ships (semiempirical models and particularly the Lloyd's Register method can be used [17]), for road traffic noise (for example the CETUR model [27]) and for rail traffic noise (for example the MITHRA-FER model developed by the CSTB in collaboration with the France SNCF [28]).

Reducing environmental impact

In the following are reviewed the technologies to reduce environmental impact by ships activities as introduced or discussed mainly by IMO. Furthermore, methodologies to reduce pollution by loading and unloading of materials and vehicles from ships will be discussed in short.

For other sources it's possible to use the concept of best available technologies as, for example, introduced by Council of the European Communities Directive concerning integrated pollution and prevention control [10].

Pollution of air

In 1997 the International Maritime Organization [29] adopted a global cap of 4.5% m/m on the sulphur content of fuel oil and provisions allowing for special Sulphur Oxides Emission Control Area to be established with more stringent control on sulphur emissions (the sulphur content of fuel oil used on board ship does not exceed 1.5% m/m or an exhaust gas cleaning system is applied to reduce the total emission of sulphur oxides from ships, including both auxiliary and main propulsion engines, to 6.0 g sulphur oxides/kWh or less calculated as the total weight of sulfur dioxide emission).

The Baltic Sea is designated as Sulphur Oxides Emission Control Area in the Protocol and North Sea in the last IMO Marine Environment Protection Committee on March 2000. Other sea areas, including ports, can be designated by the Organization, after a proposal submitted by contracting States to the Protocol of 1997, if supported by a demonstrated need to prevent, reduce, and control air pollution from sulphur oxides emissions from ships.

In the same context IMO approve technical code on nitrogen oxides emissions reductions. The reductions will affect new diesel engines with a power output of more than 130 kW, which is installed in ships, built on, or have a major modification, after January 1, 2000. The following limits on nitrogen oxides emissions from diesel engines are introduced:

- 17.0 g/kWh when n is less than 130 rpm
- 45. * n-0.2 g/kWh when n is 130 or more but less than 2000 rpm
- 9.8 g/kWh when n is 2000 or more

where n = rated engine speed (crankshaft revolutions per minute).

The operation of a diesel engine is permitted when an exhaust gas cleaning system or any other equivalent method is applied to reduce onboard nitrogen oxides emissions at least to the previous specified limits.

Concerning ships, an in-depth analysis of technologies for reducing emissions has been recently made during the MEET project [13] with regards to primary (reduction of generated emissions) and secondary (abatement systems) available control technology.

Sulphur Oxides control by primary methods can be obtained reducing fuel sulphur contents and by secondary methods with scrubber – seawater-washing system.

Nitrogen Oxides reduction by primary methods can be obtained with combustion modification, injection timing retard, modified injectors, Miller systems & turbocharging with aftercooling, fumigation of intake air, lowering maximum gas temperature in the cylinder, exhaust gas recirculation, non catalytic reduction, fuel substitution, water injection, water/diesel mixture, methanol, clean diesel, new ship design & modification; control by secondary methods with selective catalytic reduction, scrubber – seawater washing system.

Pollution of water

The Marine Environment Protection Committee (MEPC) of the International Maritime Organization has established an anti-fouling Working Group to develop a legal instrument to regulate the use of shipboard anti-fouling systems,

in particular to phase out those containing organotins such as tributyltin (TBT). The IMO Assembly in November 1999 approved the holding of a diplomatic conference in 2001 to adopt the proposed instrument. The instrument should ensure a global prohibition on the application of organotin compounds which act as biocides in anti-fouling systems on ships by 1 January 2003, and a complete prohibition on the presence of organotin compounds which act as biocides in anti-fouling systems on ships by 1 January 2008.

Another MEPC Working Group will continue developing draft new regulations for ballast water management. Current options for preventing the spread of harmful aquatic organisms in ballast water include exchanging the ballast water in deep ocean, where there is less marine life and where organisms are less likely to survive. Other options include various (filtration, thermo, chemical, and radiation) treatments of the ballast water en route to kill the living organisms

In order to be able to minimize the pollution from port operation guidelines must be produced containing recommendations on preferred handling methods for different type of liquid products.

Pollution of soil

In order to be able to minimize the pollution from port operation a guideline must be produced containing recommendations on:

- preferred handling methods for different type of bulk products
- preferred storage methods for the minimizing of pollution from stored materials.

Wastes production

The 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter [30] prohibits the dumping of certain hazardous materials, requires a prior special permit for the dumping of a number of other identified materials and a prior general permit for other wastes or matter.

"Dumping" has been defined as the deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures, as well as the deliberate disposal of these vessels or platforms themselves.

A Manual on Shipboard Waste Management has been finalized by IMO MEPC 38 (10 July 1996) in order for shipowners to prepare a garbage management plan. This manual provides guidelines and offers information and technical data and suggested tools to assess, develop and implement a waste management plan. It is designed to meet the objective of the International Safety Management (ISM) Code.

The Marine Environment Protection Committee will consider draft Guidelines on the provision and use of port waste reception facilities, developed by an MEPC correspondence group on reception facilities. The Guidelines contain information for the provision and improvement of port waste reception facilities and provide information relating to the ongoing management of existing facilities, as well as for the planning and establishment of new facilities.

Maritime Engineering and Ports II, C.A. Brebbia & J. Olivella (Editors)

The lacks of reception facilities for dirty ballast water, waste oil and garbage is still a major problem in some areas for the shipping industry.

Waste minimization and pretreatment emerge as areas for future development and waste audit is a tool that could also reflect an innovative route. Treatment technologies (compactors, shredders, pulpers, and heat compaction devices) exist for shipboard volume reduction of plastics, paper, metals, glass and food waste. Complete waste treatment systems are available for cruise liners and merchant ships. Owing to a lack of space for most of the technical installations on board, manufacturers have developed new standards for minimizing space requirements. A waste treatment plan should be designed for the flexible treatment and storage of waste. The aim should be to reduce, reuse and recycle [16].

Noise generation

In the last year the need to supply a more high comfort level to ship passengers and board personnel, as guarantee of the respect of the laws in force on noise and vibration, has urged the shipyards to take into account the problem of noise from ships seriously. The shipyard is often forced to adopt measures in order to face ambient noise and/or structural noise, turning to specialized companies. Often the only acoustical insulation of the areas of interest is not enough to guarantee the silence desired and therefore the research is addressed to minimize the noise in these areas insulating in an appropriate way the sources of noise.

In 1982 IMO developed a Code on Noise Levels on Board Ships [31], to stimulate and promote noise control at a national level within the framework of internationally agreed guidelines. In the resolution were reported recommended noise levels for specified ships areas (crew cabins, offices, recreation rooms, engine control room, etc.).

In order to be able to minimize the noise emissions from road and rail traffic in port, specific measure must be taken such as:

- preferred taxing and shipping operation modes,
- preferred taxing and shipping design area,
- physical means to reduce noise propagation
- suggestion in port traffic management.

Conclusions

In the paper an integrated approach to ports pollution from ships, other port activities and industrial activities in port is presented. The proposed methodology is useful to quantify the emissions and diffusion of pollutants in the different environmental media. Major efforts in evaluate factors to quantify emissions in water and soils appear to be necessary.

Finally a complete review of international initiatives to control and reduce pollution is reported. These initiative can be not sufficient, in port areas often integrated in urban areas, in prevision of a future rapid grow of maritime transport.

Maritime Engineering and Ports II, C.A. Brebbia & J. Olivella (Editors)

References

[1] Commission of the European Communities, Directorate General for transport, Research, Technological Development and demonstration Programme in the field of Transport, *Waterborne Transport, Additional information document*, December 1995.

[2] Briggs D.J., *An integrated emissions inventory for Europe*, Final report of feasibility study on behalf of The European Environment Agency Task Force, Institute of Environmental and Policy Analysis, University of Hudderspield, Research Report No. 93/1, 1993.

[3] Poulamaa M., *NOSE – Nomenclature for sources of emissions*, Meeting of the Join Eurostat/EFTA Group, working group "Statistics of the Environment", sub-group "Integrated Emissions Statistics", 14-15 February 2000.

[4] Economopoulos A.P., *Assessment of sources of air, water, and land pollution. A guide to rapid source inventory techniques and their use in formulating environmental control strategy. Part one: Rapid inventory techniques in environmental pollution,* World Health Organization, Geneva, 1993.

[5] EMEP/CORINAIR Task Force on Emission Inventories, *Atmospheric Emission Inventory Guidebook, Second edition*, Edited by Gordon McInnes, European Environment Agency, February 1999.

[6] United States Environmental Protection Agency, *Compilation of Air Pollutant Emission Factors: Volume I: Stationary Point and Area Sources,* AP-42, Fifth Edition, January 1995.

[7] Netherlands Ministry of health and environmental protection *Handbook of emission factors. 1. Non industrial sources.* Government Publishing Office, The Hague, The Netherlands, 1980.

[8] Netherlands Ministry of health and environmental protection (1984) *Handbook of emission factors. 2. Industrial sources.* Government Publishing Office, The Hague, The Netherlands, 1984.

[9] Organization for Economic Co-operation and Development, *Pollutant releases and transfer registers (PRTRS). A tool for environmental policy and sustainable development. Guidance manual for governments*, Paris, 1996.

[10] Council of the European Communities, *Council Directive 96/61/CE concerning integrated pollution and prevention control,* Official Journal of the European Communities, N. L 257/26 of 10 October 1996.

[11] Trozzi C., Vaccaro R., Trobbiani R., Digiovandomenico P., Piscitello E., Emissions inventory software tools for air quality management plans, *Emission Inventory: living in a global environment*, December 8-10, 1998, New Orleans.

[12] Trozzi C., Vaccaro R., *Ships transport,* in: European Commission, Transport Research fourth framework programme strategic research DG VII – 99, *Meet, Methodologies for calculating transport emissions and energy consumption*, European Communities 1999.

[13] Trozzi C., Vaccaro R., Methodologies for estimating air pollutant emissions from ships, *Proceedings of 22nd CIMAC International Congress on Combustion Engines*, Copenhagen, May 18-21, 1998.

[14] Trozzi C., Vaccaro R., Air Pollutant Emissions from ships: high Tyrrhenian Sea ports case study, *Proceedings of PORTS 98*, Genoa, Italy, September 28-30, 1998.

[15] Trozzi C., Vaccaro R., Actual and future air pollutant emissions from ships. *8TH International Symposium Transport and Air Pollution*, Graz, Austria, 31 May-2 June 1999.

[16] European Commission, Transport Research fourth framework programme strategic research DG VII – 99, *The "EMARC" project. Marpol rules and ship generated waste*, Final report for publication, March 1998.

[17] Holland C.G., Wong S.F., Noise prediction and correlation with full scale measurement in ships *Trans. ImarE*, Vol. 107, pp. 195-207.

[18] Yakamini R., Chang S.C., Smith K.S. Noise generation in marine motors *Trans. ImarE*, Vol. 107, pp. 195-207.

[19] Det Norske Veritas. Decommissioning of ships, Environmental protection and ship demolition practices. Report No. 99-3065, Revision No. 03.

[20] Chang J.C., Han K.J., User's Guide for Offshore and Coastal Dispersion (OCD) model. Version 5. Earth Tech, Inc. on contract of U.S. Department of the Interior, Mineral Management Service, Gulf of Mexico OCS Region.

[21] United States Environmental Protection Agency. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. United States Environmental Protection Agency, Research Triangle Park, North Caroline 27711, September 1995.

[22] Yamartino, R.J., J.S. Scire, S.R. Hanna, G.R. Carmichael, and Y.S. Chang, The CALGRID mesoscale photochemical grid model - I. Model Formulation, *Atmospheric Environment*, 26A, 1493-1512.

[23] Scire J.S., Yamartino R.J., Carmichael G.R., Chang Y.S., *CALGRID: A mesoscale photochemical grid model. Volume II: User's Guide.*

[24] Scire J.S., Insley E.M., Yamartino R.J., Fernau M.E., *A User's Guide for the CALMET Meteorological Model.*

[25] Ambrose, R.B., Wool T.A., Connolly J.P., *WASP4, A Hydrodynamic and Water Quality Model* EPA/600/3-87/039, 1988.

[26] United States Environmental Protection Agency, *EMSOFT: Exposure Model for Soil-Organic Fate and Transport User's Guide*, EPA/600/C-97/001.

[27] Ministere de l'Environment de la Republique Francaise, Ministere des Transports, Centre d'Etudes des Transport Urbains (CETUR) *Guide du bruit des transport terrestres – Prevision de niveaux sonores,* 1980.

[28] Centre scientifique et technique du batiment *Logiciel Mithra-Fer version 2.1 Manuel technique*, Grenoble, France, 1994.

[29] International Maritime Organization (IMO), *Text of the Protocol of 1997 to amend the International Convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1978 relating thereto.*

[30] International Maritime Organization (IMO), *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, 1972.

[31] International Maritime Organization (IMO), *Code of noise levels on board ships, Resolution A.468 (XII)*, 1982.