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INDUSTRIAL POLLUTION AND CONTROL MEASURES IN ROMANIAN FOUNDRIES

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ABSTRACT: Over the last decades significant improvements have been achieved in industry regarding the control of major polluting substances and gradually the environmental impact has shifted towards the so-called diffuse sources of pollution. Nevertheless, industrial processes still account for a considerable share of the overall pollution in Europe and it is very important to further reduce their contribution to "unsustainability". The European Union (EU) has a set of common rules on permitting of industrial installations. These rules are set out in the so-called Integrated Pollution Prevention and Control Directive of 1996 (IPPC). Romania is one of the countries which became a full member of the EU and is currently in the implementation process, in order to fulfill all the obligations that apply to the Member States. A large number of these obligations derive from the IPPC Directive, which aims at the protection of the environment as a whole and the public health as well. In this framework, the paper aims to present a synthesis of the findings issued after a thorough examination of a large number of documents relevant to the Best Available Technologies. On this basis, guidelines were developed for the application of BATs for several categories of the industry branches in Romania. This paper concerns the developed guidelines for foundries. It was concluded that in order to reduce the emissions and to keep the emissions as low as necessary it is not sufficient to implement technical measures only. It is also important to consider the "human factor" in the environmental regulations. Therefore it is suggested that a log file of the maintenance actions be required to be reported in the future regulations.
KEYWORDS: environmental impact, pollution, Best Available Technology, guideline

❖ THE IPCC DIRECTIVE: CONTENT AND SPIRIT

Pollution prevention is preferable to reliance on end-of-pipe pollution control. Cleaner production encompasses production processes and management procedures that entail less use of resources than conventional technologies and also generate less waste and smaller amounts of toxic or other harmful substances. It emphasizes the human and organizational dimensions of environmental management, including good plant operation to avoid deliberate or accidental discharges. Nowadays, cleaner production aims at including everything from the drawing board to final disposal or reuse of the product.

Prior to the adoption in September 1996 of Council Directive 96/61/EC on Integrated Pollution Prevention and Control (IPPC), air and water pollution and waste disposal were generally regulated separately, while others operated some form of integrated pollution control. However, emphasis on control of pollution in a single medium, focusing particularly on air and water quality, has resulted in many cases in a poor balance of priorities for processes emitting to different environmental media, and inconsistency in the environmental standards achieved. This is set to change with the implementation of the IPPC Directive, which aimed at the introduction of a Europe-wide system of integrated pollution prevention control to achieve a high level of protection for the environment as a whole, and to establish a general and common framework of integrated pollution control. This means that no medium will be compromised in order to protect another. Instead of independently concentrating on air, water and land, the IPPC Directive focuses on controlling the source of pollution where emissions from a facility will be preferentially eliminated, reduced, recovered or recycled. In the case where pollutant emissions cannot be prevented they will be treated using the best available 'end-of-pipe' treatment technologies [1].

IPPC sets the standards for all activities for which environmental permits are required. The permitting system that needs to be established, in the framework of the IPPC Directive, shall be integrated, considering the environment as a whole. The permits shall cover both direct and indirect discharges to any medium, as well as issues of waste minimization, energy efficiency, resource utilization, prevention of accidents, and the restoration of sites after the industrial activity has ceased. Permits shall be re-examined and updated at periodic intervals, especially when excessive pollution occurs, or when technical or other developments allow a significant reduction in emissions at a reasonable cost [2].

The Directive introduces the Best Available Technologies (BATs), which are considered the most effective and advanced stage in the development of activities and their methods of operation, which indicate the practical suitability of particular techniques for providing, in principle, the basis for Emission Limit Values (ELVs) designed to prevent and, where that is not practicable, to reduce emissions and the impact to the environment as a whole.

Techniques include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned. This is a broad term to include all factors relevant to the environmental performance of an installation. Available techniques are those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages. Best available techniques are the most effective in achieving a high general level of protection to the environment as a whole. This means that all the different types of environmental impacts an installation could have, must be considered when determining which techniques are considered 'best'. It should be noted that the determination of BAT should always take into account the potential costs and benefit for the implementation of the measures. This means that although environmental protection is the core issue of the IPPC Directive other factors such as economic and social need to be considered as well, in order to reach the most effective and feasible solution [3].

The concept of BAT plays a central role in the Directive because its objective as made clear in Article 2, "is to provide a basis for ELVs". These are primarily the ELVs set by the competent authorities as permit conditions. In addition to forming the basis for ELVs, the BAT concept provides the principal benchmark for determining the obligations of industrial operators in respect of pollution prevention and control. Although ELVs will be based on BATs, there is a provision in Article 9, which should also take account of the geographical location of the activity and local environmental conditions. Therefore, BATs can vary from place to place so that sensitive environmental problems can be addressed locally [1]. It has to be noted that the IPPC Directive does not cover health issues concerning the workers. In determining the best available techniques, special consideration should be given to the following items, [3]:

- the use of low-waste technology.
- the use of less hazardous substances.
- the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate.
- comparable processes, facilities or methods of operation, which have been tried with success on an industrial scale.
- technological advances and changes in scientific knowledge and understanding.
- the nature, effects and emissions concerned.
- the commissioning dates for new or existing installations.
- the length of time needed to introduce the best available technique.
- the consumption and nature of raw materials (including water) used in the process and their energy efficiency.
- the need to prevent or reduce to a minimum the overall impact on the environment and the risks to it.
- the need to prevent accidents and to minimize the consequences for the environment.
- the information published by the Commission or by international organizations.

FOUNDRIES: DESCRIPTION AND PRACTICES

In foundries, molten metals are cast into objects of desired shapes. Castings of iron, steel, light metals (such as aluminum), and heavy metals (such as copper and zinc) are made in units that may be independent or part of a production line. The main production steps include: *i)preparation of raw materials, ii) metal melting, iii) preparation of molds, iv) casting and v) finishing* (which includes fettling and tumbling) [6]. Electric induction furnaces are used to melt iron and other metals. However, large car component foundries and some small foundries melt iron in gas or coke-fired cupola furnaces and use induction furnaces for aluminum components of engine blocks. Melting capacities of cupola furnaces generally range from 3–25 metric tons per hour (t/h). Induction furnaces are also used in zinc, copper, and brass foundries. Electric arc furnaces are usually used in stainless steel and sometimes in copper foundries. Flame ovens which burn fossil fuels are often used for the melting nonferrous metals. The casting process usually employs non - reusable molds of green sand, which consists of sand, soot, and clay (or water glass). The sand in each half of the mold is packed around a model, which is then removed. The two halves of the mold are joined, and the complete mold is filled with molten metal, using ladles or other pouring devices.

Large foundries often have pouring furnaces with automatically controlled pouring. The mold contains channels for introducing and distributing the metal. For hollow casting, the mold is fitted with a core. Cores must be extremely durable, and so strong bonding agents are used for the core, as well as for the molds themselves. These bonding agents are usually organic resins, but inorganic ones are also used. Plastic binders are being used for the manufacture of high-quality products. Sand cores and chemically bonded sand molds are often treated with water-based or spirit-based blacking to improve surface characteristics. Centrifugal casting methods are used for pipes. Finishing processes such as fettling involves the removal from the casting of the gating system, fins (burrs), and sometimes feeders. This is accomplished by cutting, blasting, grinding, and chiseling. Small items are usually ground by tumbling, carried out in a rotating or vibrating drum, usually with the addition of water, which may have surfactants added to it.

Emissions of particulate matter (PM) from the melting and treatment of molten metal, as well as from mold manufacture, shakeout, cleaning and after-treatment, is generally of greatest concern. PM may contain metals that may be toxic. Oil mists are released from the lubrication of metals. Odor and alcohol vapor (from surface treatment of alcohol-based blacking) and emissions of other volatile organic compounds (VOCs) are also of concern. Oil and suspended solids are released into process effluents, and treatment is warranted before their discharge. Wet scrubbers release wastewaters that may contain metals. Wastewater from tumbling may contain metals and surfactants. Cooling waters, used in amounts of up to 20 m_3/t, may contain oil and some chemicals for the control of algae and corrosion. Sand molding creates large quantities of waste sand. Other wastes include slag (300–500 kg/t of metal), collected particulate matter, sludges from separators used in wastewater treatment, and spent oils and chemicals. Discarded refractory lining is another waste produced.

The primary hazardous components of collected dust are zinc, lead, and cadmium, but its composition can vary greatly depending on scrap composition and furnace additives. Nickel and chromium are present when stainless steel scrap is used. Generally, foundries produce 10 kg of dust per ton of molten metal, with a range of 5–30 kg/t, depending on factors such as scrap quality. However, induction furnaces (with emissions of 3 kg/t of molten metal) and flame ovens tend to have lower air emissions than cupolas and electric arc furnaces (EAF).

Major pollutants present in the air emissions include particulates of the order of 1000 mg/Nm^3. Foundries can generate up to 20 m^3 of wastewater per metric ton of molten metal when cooling water, scrubber water, and process water are not regulated. Untreated wastewaters may contain high levels of total suspended solids, copper (0.9 mg/l), lead (2.5 mg/l), total chromium (2.5 mg/l), hexavalent chromium, nickel (0.25 mg/l), and oil and grease. The characteristics of the wastewater will depend on the type of metal and the quality of scrap used as feed to the process. Solid wastes (excluding dust) are generated at a rate of 300–500 kg/t of molten metal. Sludges and scale may contain heavy metals such as chromium, lead, and nickel [7].

❖ IPCC IMPLEMENTATION GUIDELINES FOR FOUNDRIES

Compliance with the EU environmental acquis will inevitably improve the quality of the natural environment in Romania through:
- □ Reduced levels of air pollution,
- □ Reduced levels of water and ground contamination,
- □ The provision of suitable sanitation capacity to support tourist growth.

This overall view will have benefits in terms of increased efficiency, as well as with respect to the integration of environmental protection, [10]. We are presenting some of the developed guidelines for the implementation of the BATs for foundries in Romania that fall under the provisions of the IPPC directive. The guidelines are constituted in three parts:
- □ Control techniques: for load minimisation, for prevention of pollution, for recovery and recycling, for treating emissions.
- □ Emission limit values (ELVs).
- □ Compliance monitoring.

After thorough elaboration of data and information available in the scientific community and related to foundries, the following guidelines were developed:

POLLUTION PREVENTION AND CONTROL MEASURES

The following pollution prevention measures should be considered [6]:
- □ Prefer induction furnaces to cupola furnaces.
- □ Replace the cold-box method for core manufacture, where feasible.
- □ Improve feed quality: use selected and clean scrap to reduce the release of pollutants to the environment.
- □ Preheat scrap, with afterburning of exhaust gases.
- □ Store scrap under cover to avoid contamination of stormwater.
- □ Provide hoods for cupolas or doghouse enclosures for EAFs and induction furnaces.
- □ Use dry dust collection methods such as fabric filters instead of scrubbers.
- □ Use continuous casting for semifinished and finished products wherever feasible.
- □ Store chemicals and other materials in such a way that spills, if any, can be collected.
- □ Control water consumption by recirculating cooling water after treatment.
- □ Use closed-loop systems in scrubbers where the latter are necessary.
- □ Reduce nitrogen oxide (NOx) emissions by use of natural gas as fuel, use low-NOx burners.
- □ Reclaim sand after removing binders.

POLLUTION REDUCTION TARGETS

The recommended pollution prevention measures can achieve the target levels given below.

- AIR EMISSIONS: recover metals from collected dust. The target value for PM from furnaces and die casting machinery is not to exceed 0.5 kg/t of molten metal (after controls). The oil aerosol should not exceed 5 mg/Nm^3.
- WASTEWATER: Recycle wastewater, if any. Avoid allowing contamination of stormwater with oil; oil in stormwater should not exceed 5 mg/l.
- SOLID WASTE Reclaim sand used in molding.

TREATMENT TECHNOLOGIES

- AIR EMISSIONS: use dust emission control technologies include cyclones, scrubbers (with recirculating water), baghouses, and electrostatic precipitators (ESPs). Scrubbers are also used to control mists, acidic gases, and amines. Gas flame is used for incineration of gas from core manufacture. Target values for emissions passing through a fabric filter are normally around 10 mg/Nm3 (dry). Emissions of PM from furnaces (including casting machines used for die casting) should not exceed 0.1–0.3 kg/t of molten metal, depending on the nature of the PM and the melting capacity of the plant. At small iron foundries, a somewhat higher emission factor may be acceptable, while in large heavy-metal foundries, efforts should be made to achieve a target value lower than 0.1 kg PM per metric ton. Odors may be eliminated by using bioscrubbers.
- WASTEWATER TREATMENT: recirculate tumbling water by sedimentation or centrifuging followed by filtering (using sand filters or ultrafilters); separate oil from surface water. In the very rare cases in which scrubbers are used, recirculate water and adjust its pH to precipitate metals. Precipitate metals in wastewater by using lime or sodium hydroxide. Cooling waters should be recirculated, and polluted stormwater should be treated before discharge.

EMISSIONS GUIDELINES

The emissions levels given here can be consistently achieved by well-designed, well-operated, and well-maintainedbpollution control systems. The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is un-acceptable. All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours, [6].

- AIR EMISSIONS: air emissions of PM should be below 20 mg/Nm^3 where toxic metals are present and 50 mg/Nm^3 in other cases. This would correspond to total dust emissions of less than 0.5 kg/t of molten metal.
- LIQUID EFFLUENTS: for foundries, the effluent levels presented in Table 1 should be achieved. In Table 2 the emission limits applied in some EU member states are presented.

Table 1: Effluents from foundries

Crt. no.	Parameter	Maximum value[a]
1.	PH	6-9
2.	TSS	50
3.	Oil and grease	10
4.	Copper	0.5
5.	Zinc	2
6.	Temperature increase	<3°C[b]

a - (mg/l, except for pH and temperature).

b - The effluent should result in a temperature increase of no more than 3°C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 m from the point of discharge.

- SOLID WASTE: sludges from wastewater treatment operations should be disposed off in a secure landfill after stabilization.
- AMBIENT NOISE: noise abatement measures should achieve either the levels given below in Table 3, or a maximum increase in background levels of 3 dB(A). Measurements are to be taken at noise receptors located outside the project property boundary.

Table 2: Emission limits applied in some EU member states

Component	Limit-value (mg/Nm3)	Remark
Dust	20	Germany, TA-Luft 1986
Dust	10	Dutch, Emission guidelines (NeR)
SO2	200	Dutch, Emission guidelines (NeR)
NOx	200	Dutch, Emission guidelines (NeR)
NH_3	20	Germany, TA-Luft 1986
NH_3	200	Dutch, Emission guidelines (NeR)
VOC	20	Dutch, Emission guidelines (NeR)
Fluoride-compounds	5	Dutch, Emission guidelines (NeR)
Lead	5	Dutch, Emission guidelines (NeR)
Lead	5	Germany, TA-Luft 1986
Cr3+	5	Germany, TA-Luft 1986
Cr6+	1	Germany, TA-Luft 1986
Ni	1	Germany, TA-Luft 1986
Cd	0.2	Germany, TA-Luft 1986
Benzene	5	Germany, TA-Luft 1986
Benzo[a]pyrene	0.1	Germany, TA-Luft 1986

Table 3: Maximum acceptable noise level

Receptor	Maximum allowable log equivalent (hourly measurements), in dB(A)	
	Day (07:00-22:00)	Night (22:00-07:00)
Residential, institutional, educational	55	45
Industrial, commercial	70	70

MONITORING AND REPORTING

Air emissions should be monitored continuously for PM using an opacity meter (for an opacity level of less than 10%). Wastewater discharges should be monitored daily except for metals, which may be monitored monthly or when there are process changes. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Records of monitoring results should be kept in an acceptable format. The results should be reported to the responsible authorities and relevant parties, as required.

❖ EMISSION MITIGATION – PROPOSED MEASURES FOR ROMANIAN FOUNDRIES

In Table 4, a comparison is made between the techniques generally applied and the techniques already applied in Romanian foundry. Special attention has to be paid to the selection and the quality of the raw materials (cast iron) to prevent unnecessary emissions to the air during the melting process. At the foundry, a cupola oven is used for melting the iron and a Venturi scrubber is used to clean the air. Considering the results of the dust measurements, which exceed the emission limits used in the EU, this installation is not applying BAT. The reason for this lack of performance is malfunction of the scrubber, bad design or bad maintenance of this equipment. Furthermore it was observed that the contaminated water is released to the surrounding area, which is considered as a shift of the environmental problem from air to the soil.

Table 4: Comparison between generally applied and existing techniques

Process	Emission characteristics	General applied techniques	Installed
Metal melting	Dust, SO_2, CO, VOC, NOx metaloxides	Wet scrubbers; Dry collectors	Wet scrubbers installed, odor and thick plume noticed during production, emission limits above guidelines
Sand preparation	Dust	Incinerations	Cyclones installed, minor fugitive emission
Mould and core production	Dust, VOC	Fabric filters	VOC emission detected, no suction or treatment system
Pouring, casting	Dust, CO, VOC	Suction; No specific treatment	Observed closed
Finishing	dust	Closed production; Fabric filters	

The emissions during casting are not collected or treated. There is no need to treat the air from the casting process because the composition of the mould depends upon bentonite. The following measures are suggested:

☐ PROCESS INTEGRATED MEASURES

- Investigation of the possibilities to use alternative binder materials
- Use quality criteria to select scrap metal that will be molten in the oven
- Set up a maintenance program where the equipment is maintained on a regular basis
- Keep a log-file where the results of the inspections and measurements of every installation is described.
- Give training to people on the working floor and teach the basics of ‘good housekeeping’.

☐ TECHNICAL MEASURES

- Upgrade and optimize existing scrubbers or install new techniques by
- Repairing and cleaning the scrubber, spraying nozzles and droplet collector
- Increasing the amount of washing water
- Introducing chemicals in the washing water to remove specific (organic) compounds
- Suction of released fumes during casting and emission through a stack if resins are used as a binder material
- Find solution for disposal of contaminated washing water and waste from cupola oven.

☐ REGULATIONS

- Regulate emission limits for dust, SO_2, NOx and CO and eventually VOC
- Prescribe an investigation of the possibility to collect the diffusive emissions during casting and allow their release at a height if the investigation of the possibilities of the use of alternatives proves to be negative
- Provide regulation to be sure that the contained water and melting waste (slag) from the oven is disposed properly.

❖ CONCLUDING REMARKS

Nowadays, the need for integrated prevention and control of pollution is unquestionable. Although specific techniques are not obligatory and their application lay on self-imposed grounds, the concept of BATs is underlined as it provides a basis for setting ELVs. Furthermore, it establishes the principal benchmark for determining the obligations of industrial operators in respect of pollution prevention and control. Therefore, coordinated efforts are needed on behalf of industry, the Ministry of Environment and the local competent authorities for the elaboration of studies in order to determine BATs, to trace and address adequately the sensitive environmental issues. In this framework, financial incentives should be given to industrial operators to overcome the reluctance of traditional techniques and apply BATs. Then, the implementation of a pilot IPPC application should take place, on behalf of selected plants and a relevant licensing from the competent authorities. Finally, the planning- out and the implementation of an action plan is essential in order to adopt the IPPC Directive.

In general, it can be stated that the Romanian foundries applies to generally accepted techniques according to European Standards. Therefore it is remarkable that these techniques do not meet the emission standards although the same are used by the Member States. The reason for this rather high dust emission might be the malfunctioning of the installed scrubbers due to engineering (not engineered to meet the rather low emission limits used in the EU) or bad maintenance of the equipment. It can be assumed that the dust emission will meet the standards by upgrading or changing the existing equipment and improving maintenance. It is also suggested that CO, VOC and SO_2 be measured on a regular basis. In any case, specific small or big technical objectives should be set, which shall be feasible and measurable and shall result in the improvement of the environmental performance of foundries.

To reduce the emissions and to keep the emissions as low as necessary it is not sufficient to implement technical measures only. It is also important to consider the 'human factor' in the environmental regulations. Therefore it is suggested that a log file of the maintenance actions be required to be reported in the future regulations.

Moreover, incentives should be established in order to promote research activities, in order to develop modern, feasible and efficient techniques to minimize the environmental impacts from the operation of the foundries.

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