

# Environment protection problems in the foundry industry – integrated evaluation

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## 1. Introduction

The foundry industry is a major player in the recycling of metals. Steel, cast iron and aluminium scrap is re-melted into new products. Most possible negative environmental effects of foundries are related with the presence of thermal processes and the use of mineral additives. Environmental effects therefore are mainly related with the exhaust and off-gases and with the re-use or disposal of mineral residues. Emissions to air are the key environmental concern. The foundry process generates mineral dusts, acidifying compounds, products of incomplete combustion and volatile organic carbons. Dust is a major issue, since it is generated in all process steps, in varying types and compositions. Dust is emitted from metal melting, sand moulding, casting and finishing. The foundry process involves various emission sources (e.g. from hot castings, sand, hot metal). A key issue in emission reduction is not only to treat the exhaust and off-gas flow, but also to capture it. Since foundries deal with a thermal process, energy efficiency and management of the generated heat are important environmental aspects. However, due to the high amount of transport and handling of the heat carrier (i.e. the metal) and its slow cooling, the recovery of heat is not always straightforward. Foundries may have a high water consumption, e.g. for cooling and quenching operations. In most foundries, water management involves an internal circulation of water, with a major part of the water evaporating. The water is generally used in cooling systems of electric furnaces (induction or arc) or cupola furnaces. In general, the final volume of waste water is very small. Nevertheless, when wet dedusting techniques are used, the generated waste water requires special attention. In high pressure die-casting, a waste water stream is formed, which needs treatment to remove organic (phenol, oil) compounds before its disposal.

## 2. Best available techniques (BAT) for foundry processes

One of the most important issues of the IPPC Directive [1] is the application of BAT principle. The BAT descriptions contain mainly [2]:

- characteristics of the process technology,
- specific production of emissions, waste and by-product generation, needs to consumptions of raw materials and energy inputs;
- the most effective technologies related to decreasing of emissions and waste rates and to increasing of energy savings;
- identification of BAT technologies;
- the new and developed technologies and processes.

### 2.1. General BAT for foundry processes

Some BAT elements are general and apply for all foundries, regardless of the processes they apply and the type of products they produce. This concerns material flows, finishing of castings, noise, waste water, environmental management and decommissioning.

*Material flows.* The foundry process involves the use, consumption, combination and mixing of various material types. BAT requires the minimisation of raw material consumption and further residue recovery and recycling. Therefore, BAT is to optimise the management and control of internal flows.

*BAT for material flow:*

1. apply proper storage and handling methods for solids, liquids and gases;
2. apply the separate storage of various incoming materials and material grades preventing deterioration and hazards;
3. carry out storage in such a way that the scrap in the storage area is of an appropriate quality for feeding into the melting furnace and that soil pollution is prevented;
4. apply internal recycling of scrap metal;
5. apply separate storage of various residue and waste types to allow re-use, recycling or disposal;
6. use simulation models, management and operational procedures to improve metal yield and optimise material flows;
7. implement good practice measures for molten metal transfer and ladle handling.

*Finishing of castings.* For abrasive cutting, shot blasting and fettling, BAT is to collect and treat the finishing off-gas using wet or dry system. The BAT associated emission level for dust is 5 - 20 mg/Nm<sup>3</sup>.

*BAT for heat treatment:*

1. use clean fuels (i.e. natural gas or low level sulphur content fuel) in heat treatment furnaces;
2. use automated furnaces operation and burner/heater control;
3. capture and evacuate the exhaust gas from heat treatment furnaces.

Noise reduction:

*BAT for noise reduction:*

1. develop and implement a noise reduction strategy, with general and source specific measures;
2. use enclosure systems for high-noise unit operations such as shake-out;
3. use additional measures, according to local conditions.

Waste water.

*BAT for waste water:*

1. keep waste water types separate according to their

- composition and pollutant load;
2. collect surface run-off water use oil interceptors on collection system before discharge to surface water;
  3. maximise the internal recycling of process water and the multiple used of treated waste water;
  4. apply waste water treatment for scrubbing water and the other waste water flow.

*Reduction of fugitive emissions.* BAT is to minimise fugitive emissions arising from various non-contained sources in the process chain, by using a combination of different measures. The emissions mainly involve losses from transfer and storage operations and spills. Fugitive emission may arise from the incomplete evacuation of exhaust gas from contained sources, e.g. emission from furnaces during opening or tapping. BAT is to minimise these fugitive emissions by optimising capture (nearest to the source) and cleaning of fume.

*BAT for reduction of fugitive emission:*

1. avoid outdoor and uncovered stockpiles, but where outdoor stockpiles are unavoidable, use sprays, binders, stockpiles management techniques, windbreaks, etc.;
2. cover skip and vessels;
3. vacuum clean the moulding and casting shop in sand moulding foundries;
4. clean wheels and roads;
5. keep outside doors shut;
6. carry out regular housekeeping;
7. design hooding and ducting to capture fume arising from hot metal, furnace charging, slag transfer and tapping;
8. apply furnace enclosures to prevent the release of fume losses into atmosphere.

*Decommissioning.* BAT is to apply all necessary measures to prevent pollution upon decommissioning. In these measures, at least the following processes part are considered: tanks, vessel, pipework, insulation, lagoons and landfills.

*BAT for decommissioning:*

1. minimize later risks and costs by careful design at the design stage;
2. develop and implement an improvement program for existing installations;
3. develop and maintain a site closure plan for new and existing installations.

## 2.2. BAT for particular foundry processes

### 2.2.1. Ferrous metal melting

Steel is melted in both electric arc furnaces (EAF) and induction furnaces (Table 1). For cast iron: cupola, electric arc, induction and rotary furnaces are applicable.

Table 1  
Emission to air associated with the use of BAT for ferrous metal melting and treatment

Parameter	Emission level
Dust <sup>(1)</sup>	5 - 20 mg/Nm <sup>3</sup>
PCDD/PCDF	≤ 0.1 ng TEQ/Nm <sup>3</sup>

(1) The emission level of dust depends on the dust components, such as heavy metals, dioxins and its mass flow

*BAT for ferrous metal melting process.*

*For the operation of electric arc furnaces BAT is:*

1. applying reliable and efficient process controls to shorten the melting and treatment time;
2. using the foamy slag practice;
3. efficiently capturing the furnace off-gas;
4. cooling the furnace off-gas and dedusting using a bag filter (Table 2);
5. recycling the filter dust into EAF furnace.

*For the operation of cupola furnaces BAT is:*

1. using divided blast operation (2 rows of tuyeres) for cold blast cupolas;
2. using oxygen enrichment of the blast air with oxygen levels 22 – 25% (i.e. 1 – 4% enrichment);
3. minimising the blast-off periods for hot blast cupolas by applying continuous blowing or long campaign operation;
4. using coke with known properties and of a controlled quality;
5. cleaning furnace off-gas by collection, cooling and dedusting using a bag filter or wet scrubber (Table 3);
6. applying post combustion off-gas and heat recovery;
7. evaluating the possibility of waste heat utilisation from holding furnaces in duplex configuration;
8. using wet scrubber system when melting with basic slag (basicity up to 2);
9. preventing and minimising dioxins and furan emission to a level below 0.1 ng TEQ/Nm<sup>3</sup>;
10. minimising slag forming;
11. pretreating the slags in order to allow their external re use;
12. collecting and recycling coke breeze.

Table 2  
Emission to air associated with the use of BAT for the EAF melting of ferrous metals

Parameter	Emission level mg/Nm <sup>3</sup>
NO <sub>x</sub>	10 - 50
CO	200

Table 3  
Emission to air associated with the use of BAT for the cupola melting of ferrous metals

Type	Parameter	Emission level, mg/Nm <sup>3</sup>
Hot blast	CO	20 - 1000
	SO <sub>2</sub>	20 - 100
	NO <sub>x</sub>	10 - 200
Cold blast	SO <sub>2</sub>	100 - 400
	NO <sub>x</sub>	20 - 70
	NM - VOC	10 - 20
Cokeless	NO <sub>x</sub>	160 - 400

*For the operation of induction furnaces BAT is to:*

1. melt clean scrap, avoiding rusty and dirty inputs and adhering sand;
2. use good practice measures for the charging and operation;
3. use medium frequency power;
4. to evaluate the possibility of waste heat recuperation.

tion and under specific conditions to implement a heat recovery system;

- use a hood, lip extraction or cover extraction on each induction furnace to capture the furnace off-gas and maximise the off-gas collection during the full working cycle;
- use dry flue-gas cleaning and keep dust emissions below 0.2 kg/tonne molten iron.

*For the operation of rotary furnaces BAT is to:*

- implement measures to optimise furnace yield and to use an oxyburner;
- collect the off-gas close to the furnace exit, apply post combustion, cool it using a heat-exchanger and then to apply dry dedusting (Table 4);
- prevent and minimise dioxins and furan emissions to a level below 0.1 ng TEQ/Nm<sup>3</sup>.

Table 4

Emissions to air associated with the use of BAT for the rotary melting of ferrous metals

Parameter	Emission level, mg/Nm <sup>3</sup>
SO <sub>2</sub>	70 - 130
NO <sub>x</sub>	50 - 250
CO	20 -30

### 2.2.2. Non-ferrous metal melting

For aluminium melting multiple furnace types are applied. For melting of copper, lead and zinc and their alloys, induction or crucible furnaces are used. For copper alloys, hearth type furnaces are used as well. For magnesium melting, only crucible furnaces are used. A cover gas is used to prevent oxidation.

*BAT for induction furnaces melting aluminum, copper, lead and zinc:*

- use good practice measures for charging and operation;
- use medium frequency power;
- evaluate the possibility of waste heat recuperation;
- minimise emissions and if needed collect the furnace off-gas, maximising the off-gas collection during the full working cycle and apply the dry dedusting.

BAT for the degassing and cleaning of aluminium is to use a mobile or fixed impeller station with Ar/Cl<sub>2</sub> or N<sub>2</sub>/Cl<sub>2</sub> gas.

Table 5

Emissions to air associated with the use of BAT in the melting of aluminium

Furnace type	Parameter	Emission level, mg/Nm <sup>3</sup>
General	Chlorine	3
Shaft	SO <sub>2</sub>	30 – 50
	NO <sub>x</sub>	120
	CO	150
	VOC	100 - 150
Hearth	SO <sub>2</sub>	15
	NO <sub>x</sub>	50
	CO	5
	TOC	5

For melting of magnesium in installations with an annual output of 500 tonnes and more BAT is to use SO<sub>2</sub> as a covering gas. For smaller plants BAT is to use SO<sub>2</sub> or

to minimise SF<sub>6</sub> consumption and emissions. In the case where SF<sub>6</sub> is used the consumption level is < 0.9 kg/t castings for sand casting and < 1.5 kg/t castings for pressure die-casting.

BAT for emission dust for non-ferrous metal melting and treatment is 1-20 mg/Nm<sup>3</sup>. The emission factor associated with BAT for dust emission from aluminium melting is 0.1-1 kg/t of molten aluminium (Table 5). In order to comply with these BAT associated emission levels it may be necessary to install a flue-gas cleaning installation; in this case BAT is to use dry dedusting.

### 2.2.3. Lost mould casting

Lost mould casting involves moulding, core-making, pouring, cooling and shake-out. This includes the production of green sand or chemically-bonded sand moulds and chemically-bonded sand cores.

*BAT for lost mould casting process.*

*Green sand moulding:*

- mixing of sands, clay binder and necessary additives may be done in atmospheric or vacuum mixers, for vacuum mixing, an additional condition is that the sand capacity needs to be higher than 60 t/h;
- enclose all the unit operations of the sand plant and to dedust the exhaust gas.
- apply primary regeneration.

*Chemically-bonded sand mould and core-making:*

- minimize the binder and resin consumption and sand losses, using control measures;
- capture exhaust gas from the area where cores are prepared, handled and held prior to dispatching;
- use water-based coatings and replace alcohol-based coatings for refractory coating of moulds and cores, where it is possible; when alcohol-based coatings are used BAT is to provide evacuation at the coating stand, using movable or fixed hoods;
- treat the evacuated exhaust gas; for amine-hardened urethane-bonded (cold-box) core preparation the amine emission can be maintained below 5 mg/Nm<sup>3</sup>;
- minimize the amount of sand going to disposal, by adopting a strategy of regeneration and/or reuse of chemically-bonded sand (as mixed or monosand).

In Table 6 emission levels associated to the BAT measures for lost mould casting process are given.

Table 6

Emission to air associated with the use of BAT for moulding and casting using lost moulds

Emission source	Parameter	Emission level, mg/Nm <sup>3</sup>
General	Dust	5 - 20
Core shop	Amine	5
Regeneration unit	SO <sub>2</sub>	120
	NO <sub>x</sub>	150

### 2.2.4. Permanent mould casting

Permanent mould casting involves the injection of molten metal into a metal mould. Chemically-bonded sand cores are used to a limited extent in gravity and low-pressure die-casting.

*BAT for permanent mould casting process:*

1. minimize the consumption of the release agent and water;
2. collect run-off water into a waste water circuit for further treatment;
3. collect water leakage liquid from hydraulic system into a waste water circuit for further treatment, using oil interceptors and distillation, vacuum evaporation or biological degradation;
4. enclose the decorating unit, and treat the exhaust gas using wet or dry dedusting.

### 3. Conclusions

The environmental effects of a foundry process mainly are related to the exhaust and off-gasses and the re-use or disposal of mineral residues. The foundry industry is a differentiated and diverse industry [3, 4]. The elements of BAT applicable to a specific foundry need to be selected according to the type of activity. The emission and consumption levels associated with the used BAT have to be seen together with any specified reference conditions. Data concerning costs have been taken into account together with the description of the techniques. The actual cost of applying a technique will depend strongly on the specific situation regarding, for example, taxes, fees, and technical characteristics of the installation concerned [5].

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### References

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APLINKOS APSAUGOS PROBLEMAS  
LIEJININKYSTĖS PRAMONĖJE KOMPLEKSINIS  
ĮVERTINIMAS

Re z i u m ė

Straipsnyje nagrinėjama kompleksinė saugos technikos ir teršimo kontrolės direktyva ir jos pritaikymas liejininkystės pramonėje. Svarbiausi šios direktyvos principai yra oro užteršimo mažinimas, efektyvus žaliavos ir energijos naudojimas, cheminio utilizavimo proceso opti-

mizavimas, gamybos atliekų regeneravimas ir antrinis panaudojimas bei kenksmingų medžiagų pakeitimas kitomis. Iš specifinės taršos aplinkai pozicijos aptariamos šios pagrindinės veiklos sritys: lydimas ir metalo apdorojimas, formų ir gurgučių gamyba, išlydyto metalo pylimas į liejimo formas, aušinimas kietėjimo metu, liejinių išėmimas iš formų ir jų baigiamasis apdirbimas. Liejykloms svarbiausia yra oro teršimas, efektyvus žaliavų ir energijos naudojimas, atliekų mažinimas kartu su reneneravimo ar pakartotinio naudojimo galimybėmis.

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ENVIRONMENT PROTECTION PROBLEMS IN THE  
FOUNDRY INDUSTRY – INTEGRATED  
EVALUATION

S u m m a r y

The papers deals with Integrated Prevention and Pollution Control (IPPC) Directive and its application in foundry industry. The minimization of emissions, efficient raw material and energy usage, optimum process chemical utilization, recovering and recycling of waste and the substitution of harmful substances are all important principles of the IPPC Directive. The following major activities are discussed from the point of view of specific pollution to environment: melting and metal treatment, preparation of moulds and cores, casting of molten metal into the mould, cooling for solidification and removing the casting from the mould, finishing of the raw casting. For foundries the focal points are air emissions, the efficient use of raw materials and energy, and waste reduction, in conjunction with any recycling and re-use options.

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ПРОБЛЕМЫ ОХРАНЫ ОКРУЖАЮЩЕЙ СРЕДЫ В  
ЛИТЕЙНОМ ПРОИЗВОДСТВЕ – КОМПЛЕКСНАЯ  
ОЦЕНКА

Р е з ю м е

В статье обсуждается общая директива о контроле техники безопасности и загрязнения и ее применения в литейном производстве. Главные принципы этой директивы заключаются в следующем: уменьшение выбросов, эффективное использование сырья и энергии, оптимизирование процессов химической утилизации, регенерация и вторичное использование производственных отходов, а также замена вредных материалов другими. С позиции специфического загрязнения среды обсуждаются следующие сферы деятельности: плавление и обработка металла, производство форм и стержней, заливка расплавленного металла в литейные формы, охлаждение во время затвердевания, извлечение отливок из форм и финишная их обработка. Для литейных заводов главными факторами являются загрязнения воздуха, эффективное использование сырья и энергии, уменьшение отходов вместе с возможностями регенерации и повторного использования.

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