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I. UNAMUNO*, J. J. LARAUDOGOITIA*, S. M. ALMEIDA**

SIDENOR BASAURI EAF EMISSIONS REDUCTION THROUGH ANALYSIS AND MODELLING

REDUKCJA EMISJI ZANIECZYSZCZEŃ Z PIEACA ŁUKOWEGO HUTY BASAURI SIDENOR PRZEZ ANALIZĘ I MODELOWANIE

The steel industry has been facing new social and environmental demands. In particular, environmental conservation is one of the most important issues for survival of the steel industry in the twenty first century. Cost-effective solutions are to be sought, in order to enable the European steelmakers to contribute to cleaner ambient air and simultaneously maintain their competitiveness on the world market.

The work presented in this paper is based on a project under RFCS Programme in order to investigate the formation mechanism of highly toxic micropollutants, such as VOCs and SVOCs, from the electric arc furnace of Sidenor Basauri Works. The study allows knowing relationships between measurements of pollutants and operational parameters of the production process, so that an abatement of emissions could be achieved. From the results of this study, it is possible to determine the characteristic fingerprint of micropollutants emitted from the EAF to the atmosphere.

Keywords: Electric Arc Furnace, Environment, Emissions, PAH, PCB

Przemysł stalowy staje wobec nowych żądań społecznych i środowiskowych. Szczególnie ochrona środowiska jest jednym z najważniejszych zagadnień dla przetrwania przemysłu stalowego w dwudziestym pierwszym wieku. Szukane są opłacalne rozwiązania, umożliwiające europejskim hutom przyczynianie się do czystszego powietrza i równocześnie utrzymujące ich konkurencyjność na światowych rynkach.

Praca przedstawiona w tym artykule bazuje na programie RFCS, którego celem jest zbadanie mechanizmu tworzenia wysoce toksycznych mikrosubstancji zanieczyszczających, jak VOC i SVOC, pochodzących z pieca łukowego huty Sidenor Basauri. Badania pozwalają na określenie zależności między pomiarem zanieczyszczeń, a parametrami sterowania procesem produkcji, w celu osiągnięcia spadku emisji. Z wyników badań można określić charakterystykę daktyloskopijną mikrozanieczyszczeń emitowanych do atmosfery z pieca łukowego.

1. Introduction

SIDENOR INDUSTRIAL S.L. is a steelmaking company which produces special and stainless steel long products, devoted to a high extent for automotive applications.

Production facilities at Sidenor Basauri plant include electric arc furnace (AC), secondary metallurgy station (two ladle furnaces sharing a vacuum tank degasser and VOD) and continuous casting process followed by direct rolling.

The steel industry has been facing new social and environmental demands. In particular, environmental conservation is one of the most important issues for survival of the steel industry in the twenty first century. Important themes for the industry to solve are local and global environmental issues.

EAF plants produce waste gas containing significant amounts of pollutants like dust, heavy metals and organic compounds such as benzene, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated byphenyl (PCBs) [1]. Emissions from these plants are fairly poorly defined. As regulations on stack emissions are being tightened, careful monitoring and reduction are essential. Therefore, it is important to investigate the factors controlling the emissions of pollutants as a basis to develop effective countermeasures.

The study of the formation mechanism regarding these compounds during steel production in the EAF is quite important to define effective measures in order to

* SIDENOR I+D S.A., BARRIO UGARTE S/N, 48970 BASAURI, SPAIN
** SUSTAINABLE DEVELOPMENT DEPT., INSTITUTO DE SOLDADURA E QUALIDADE, LISBON, PORTUGAL

control these emissions by means of operational parameters.

This paper highlights the conclusions drawn for the work carried out to characterise pollutant emissions in the EAF and in the vicinity of the plant.

2. Materials and methods

Plant description

All the industrial trial heats were performed in the steelmaking of Sidenor Basauri. The gas cleaning equipment of the EAF is described schematically in Fig. 1, including the sampling location used in the trials. It was not possible to install a sample probe closer to the EAF in any other location without disturbing production activities that would enable to know better the relationships between emissions and operational conditions.

According to the Fig. 1, the gases extracted from the EAF first meet a combustion chamber. Then, gases are brought together ahead of a forced draught cooler. From there, they reach a mixing chamber, also designed as spark arrestor, where the primary gas is cooled down by mixing with part of air extracted at the canopy hood before cleaning in a jet pulse bag filter, followed by two fans evacuating into a 20 m high stack.

At Sidenor Basauri plant, an electric arc furnace operates with a tap weight of 140 ton. The production of steel is a batch process. Stages include charging, melting, refining, deslagging, and tapping. During the charging stage scrap is introduced into the EAF. The input material for the EAF is typically 100 percent scrap. The charge also includes lime and carbon. Direct reduced iron (DRI) can supplement the scrap steel used as charge material.

For the measurement campaigns carried out, several types of scrap were used, which did not necessarily represent the type of scrap used daily, but were used because one of the objectives of the investigation was to know the possible correlation between the scrap charged and the measured emissions, e.g. dust emitted.

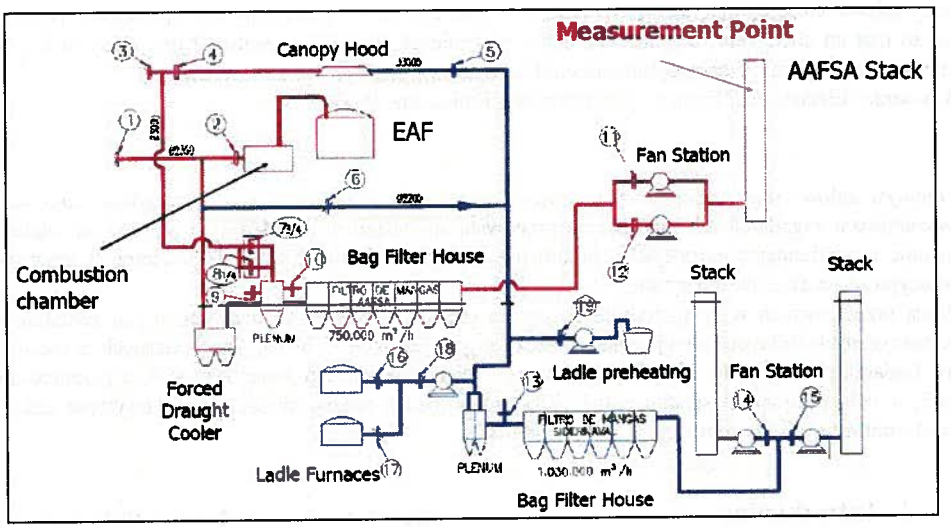

Fig. 1. Sidenor Basauri gas extraction system

Sampling of emissions from the EAF

Each trial took approximately one hour of sampling and each sampling included roof opening, scrap charge, roof closing (twice, as there were two baskets), melting, refining and tapping. The sampling started when the roof was opened and the scrap was loaded and was completed with the heat tapping. Different steel grades were chosen according to the scrap type used in each heat. In some cases the duration of the sampling was longer due to problems originated during the heat (change of electrodes, problems at the moment of the opening of EBT ...).

The measurements were performed in cooperation with ISQ in order to asses the influence of operating conditions on the generation of some selected organic substances. For the determination of VOC and PAH/PCB emissions from EAF stack, a partial volume of the flue gas – e.g. gas including dust – was extracted via a glass tube from the flue gas duct and led into the collection system. The glass probe was installed centrically in a water-cooled probe of titanium. By the means of cooling water a rapid cooling down of the sample was executed. The flow of the sampled gas stream was adjusted to obtain isokinetic conditions on the sampling nozzle.

For the determination of PAHs and PCBs, the sampling train was extracted with appropriate solvents. The extract of the condensate was used for further laboratory treatment and combined with the extract from the sampling train. The measurement was performed by means of high-resolution gas chromatography and mass spectrometry (HRGC/MS) using DB-5 capillary columns. PAH and PCB were quantified against selected deuterated labelled internal standard.

The determination of VOC emissions from stack was based on NIOSH method 1501, which consists on the collection of a gas sample trapped by condensation by means of an absorbent (charcoal carbon). The charcoal carbon was placed in vials with carbon disulphide (CS2) that allowed desorption of BTEX from the charcoal to the solution. This liquid sample was analysed then by gas chromatography.

Ambient air sampling

Ambient air monitoring campaigns were also carried out in the surroundings of Sidenor Basauri Works to determine concentrations of particles (TSP) and VOCs. Three sampling locations were selected: 1) bascule gate which is the point with the highest EAF stack and scrap trucks impact; 2) R&D building which is the point with the lowest EAF stack impact; 3) main gate which is the gate used by the workers and is consequently affected mainly by vehicles (see Fig. 2). VOC were measured continuously with the equipment Bruel & Kjaer 1302 that uses Non Dispersive Infra Red and TSP was sampled using a Graseby Andersen Hi-volume sampler. This sampler operated at a flow rate of 30 m^3h^{-1}. Filters were weighed before and after sampling.

Fig. 2. Sampling locations for ambient air monitoring

3. Results and discussion

SVOC emissions of Sidenor EAF stack

PAH and PCB may be formed as a result of incomplete combustion of organic material. This happens mainly when the temperature is too low. Also, dust can still contain traces of carbon, chlorine (in form of salts) and trace metals so that as the off gases cool down, pollutants may be formed on the surface of the dust particles.

TABLE 1

PAH average concentrations (μg/Nm3) measured in EAF stack

	Average	Minimum	Maximum	Reference[1]
Naphthalene	40	5.9	195	792
Acenaphtylene	6.9	0.23	34	19.2
Acenaphtene	1.4	0.20	18	8.28
Fluorene	3.5	0.52	19	8.28
Phenanthrene	16	2.3	70	2.65
Anthracene	2.1	0.13	11	32.7
LM-PAH	70	12	277	
Fluoranthene	5.2	1.2	17	18.5
Pyrene	2.8	0.66	8.7	14.4
Benzo(a)anthracene	0.24	0.014	1.7	1.05
Chrysene	0.90	0.13	4.3	0.73
MM-PAH	9.2	2.2	28	
Benzo(b+j+k)fluoranthene	0.46	0.046	2.3	2.8
Benzo(a)pyrene	0.055	0.0016	0.40	0.3
Benzo(ghi)perylene	0.033	0.0033	0.10	1.34
Indeno(1,2,3)-cd-pyrene	0.073	0.0039	0.53	0.86
Dibenz(ah)anthracene	0.0037	0.00070	0.018	0.21
HM-PAH	0.62	0.056	2.8	
Total US EPA PAHs	79	16	296	

Table 1 presents PAH average concentrations measured in Sidenor Basauri EAF stack and compare them with the reference values from the literature [2, 3].

Low molecular weight PAHs (2 and 3 ringed PAHs) presented the highest contribution for total PAH (85%). Medium PAHs (4 ring isomers) and high molecular weight PAHs (5, 6 and 7 isomers) were present in lower quantities. Yang et al (1998) measured PAHs in EAF and also obtained a highest contribution from LMW PAHs (78%).

The predominant compounds in PAHs were naphthalene, with an average contribution for total PAHs of 48% and average concentration of 40 µg/Nm3, and phenanthrene, with an average contribution for total PAHs of 20% and average concentration of 16 µg/Nm3 (Fig. 3).

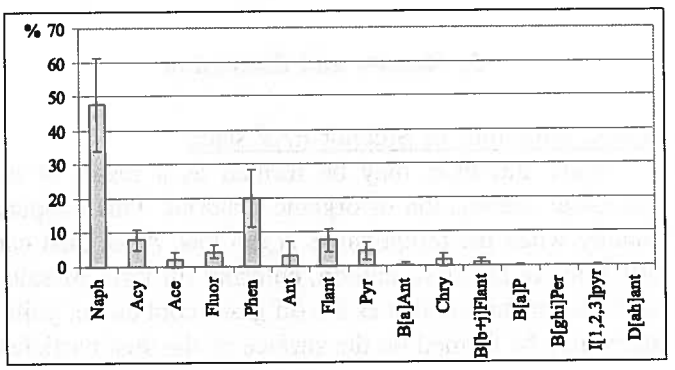

Fig. 3. Average contribution (+/- sd) species to PAH concentration (%) in EAF stack

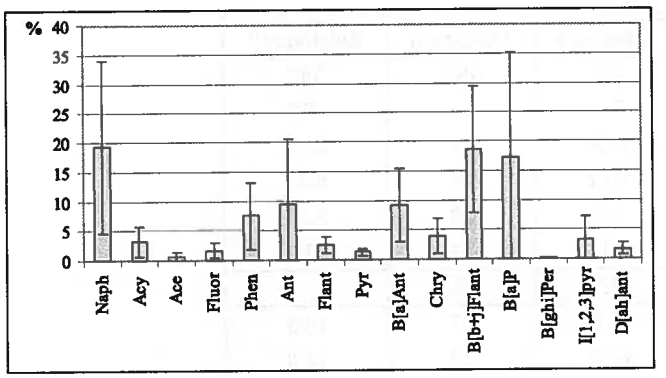

Fig. 4. Contribution (+/- sd) of PAHs to total B[a]Peq in EAF stack

In order to characterize the carcinogenic properties of the PAH EAF emissions, the concentrations of the most toxic 16 US EPA PAHs were converted into their B[a]P equivalent concentrations (B[a]eq) using the list of Toxic Equivalent Factors (TEF) established by Nisbet and Lagoy [4]. Fig. 4 presents the percent contribution of PAH to total B[a]eq in EAF stack. Naphtalene (with 19%), Benzo(a)pyrene (with 17%), benzo(b+j+k)fluoranthene (with 19%) were the compounds which contribute the most to the overall toxicity of EAF emissions.

Regarding the emission of PCBs, Fig. 5 summarise the emissions of these congeners in EAF stack during the sampling campaigns.

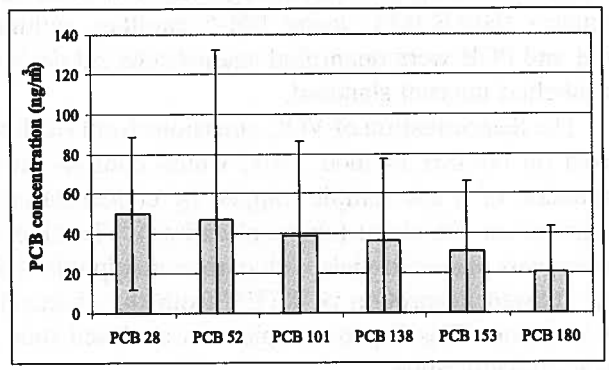

Fig. 5. Average (+/- sd) PCB concentration (ng/m^3) in EAF stack

The predominant compounds were PCB 28 (with an average contribution for total PCBs of 23%) and PCB 52 (with an average contribution for total PCBs of 21%). Standard deviation shows that there is a big difference between trials which means that process conditions influence the emission of PCBs.

VOC emissions of Sidenor EAF stack

Volatile organic compounds are generated in the furnace from combustion of auxiliary fuel, oil contained in the scrap and decarburization of some of the scrap. Fig. 6 shows the total VOC emissions measured in EAF stack. Daily average concentrations and the average of the concentrations measured during different campaigns are presented.

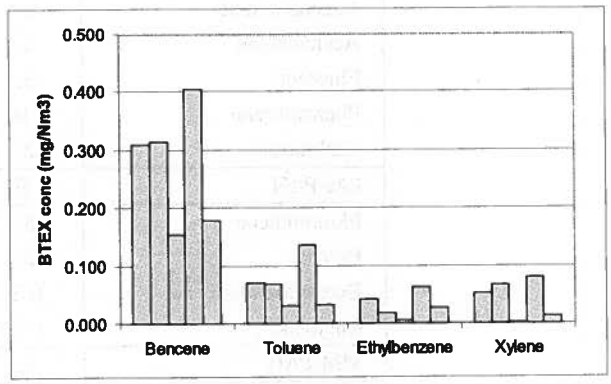

Fig. 6. VOC emissions as sum of BTEX in EAF stack

The analysis of results indicated that benzene was the major contributor for BTEX total concentration.

Ambient air data in the vicinity of the plant

Fig. 7 presents TSP concentration measured in environment in the surroundings of Sidenor Basauri Works.

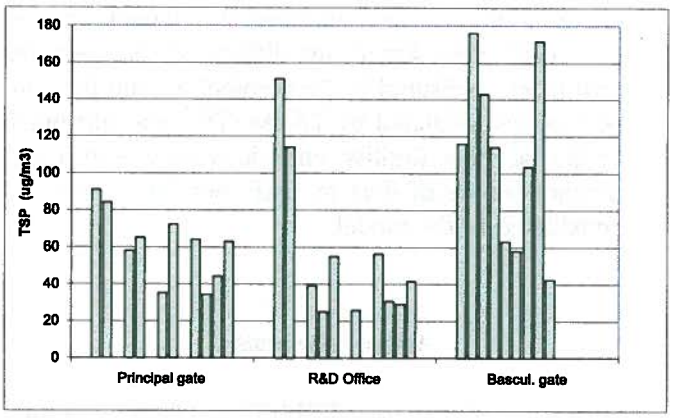

Fig. 7. TSP concentrations in Sidenor Basauri Works

Results show that the highest TSP concentrations were registered in the bascule gate. Firstly, the EAF stack is closer to this sampling point. Secondly, the dust generated by the scrap trucks and the plant fugitive emissions have a great importance for the TSP concentrations in this sampling point.

Modelling of EAF emissions

Pollutant concentrations at the ground level were calculated by dispersion modelling using TAPM software (The Air Pollution Model) [5]. TAPM requires two basic types of input data: meteorology and emissions. The ground-level pollutant concentrations were obtained on a grid of 20 km × 20 km centred in Sidenor. Fig. 8 presents TSP concentration at ground level (a – annual average; b – hourly maximum). Similar profiles were observed (varying the scale) for the rest of analysed pollutants because only EAF stack emissions were considered.

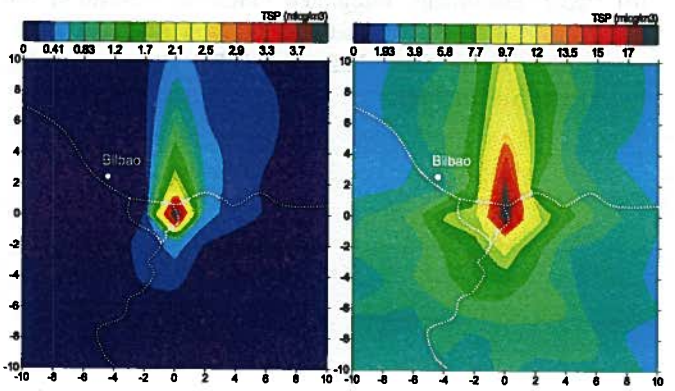

Fig. 8. TSP concentration at ground level (a) Annual average; (b) Hourly maximum value

Results from the model showed that the most unfavourable point of the grid (i.e. the place where higher concentrations should be registered) coincide with the Bascule Gate Sampling Station. Therefore modelled ground levels for the most unfavourable point of the grid were compared with the concentrations measured in this sampling point. Table 2 presents for Bascule Gate Sampling Station a) the simulated annual average; b) the simulated hourly maximum and c) the measured pollutant concentration.

As expected, Table 2 shows that the pollutant concentrations measured in this sampling point were systematically higher than the concentrations calculated by TAPM. Other sources, which have not been taken into account in the dispersion model, also contribute to the pollutant concentrations measured in the environment.

TABLE 2

Calculated pollutant ground concentrations at Bascule gate sampling point (μg/m^3). (a) annual average and b) hourly maximum; c) measured pollutant concentration

	a – Average (calculated) (μg/m^3)	b – Maximum (calculated) (μg/m^3)	c – Average (measured) (μg/m^3)
TSP	4.3	19	83
NOx	1.2	5.1	26
SO2	1.2	5.1	7.5
PAH	6.9×10^{-3}	3.1×10^{-2}	-
B[a]P	4.9×10^{-6}	2.2×10^{-5}	-
B[a]Peq	2.3×10^{-5}	1.0×10^{-4}	-
PCB	2.0×10^{-5}	8.8×10^{-5}	-
Benzene	4.1×10^{-2}	1.8×10^{-1}	1.9
Toluene	5.2×10^{-3}	2.3×10^{-2}	5.1
Ethylbenzene	2.0×10^{-2}	9.1×10^{-2}	2.5
Xylene	2.1×10^{-2}	9.5×10^{-2}	7.8

Some of these sources are associated with Sidenor Basauri production:

1. EAF gas extraction system is composed by three stacks. Measurements were performed in the main stack, being the emissions of the other two not considered in the model;
2. Fugitive emissions are significant in this industry and they were not taken into account in these calculations;
3. Dust resuspension, NOx and VOC emissions associated with the trucks that supply scrap to the plant were not estimated;
4. Emissions from the stack associated with the re-heating process were not within the study of this project and therefore they were not considered in the model.

The first three unaccounted sources could explain part of the difference between measured and calculated TSP.

4. Conclusions

- The results of the emissions and air ambient measurements carried out in Sidenor EAF stack showed that distribution of the organic compounds in the off gases from the EAF vary substantially. Changes in the composition of contaminated scrap or in the removal efficiency of the bag filters can change the distribution of the pollutants.
- Concerning the obtained values, PAH analysis showed that naphthalene was the main compound emitted by the EAF stack with an average contribution of 48% of total measured PAHs. The study of the carcinogenic properties of PAH emissions, using toxic equivalent factors, showed that naphtalene (ca. 19%), benzo(a)pyrene (ca. 17%), benzo(b+j+k)fluoranthene (ca.19%) were the compounds contributing the most to the overall toxicity of EAF emissions. Characterisation of PCBs showed that the predominant compounds in EAF emissions were PCB 28 (ca. 23% of indicator PCBs) and PCB 52 (ca. 21% of indicator PCBs). Dust emissions measurements showed that the maintenance of bag filters was the most critical factor to control in order to avoid emissions of significant concentrations of dust.
- Two strategies were available to tackle the problem of controlling the release of organics into the environment. One was the use of charging clean scrap into the EAF and the second one was a correct maintenance of the installations. Other operational changes such as working with the furnace door, minimizing operational time off periods and decreasing the duration of the roof opening for charging were demonstrated that they were also beneficial to decrease the emission of pollutants [6].
- The modelling of emissions data using TAPM to predict ground level concentrations of pollutants showed that there were significant differences between the dust levels measured in the ambient air and the concentrations predicted by TAPM. This was attributed to the fact that fugitive emissions were also a significant source of dust in EAF, but these were not considered in the model.

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