Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 22 (2016) 452 – 456

Procedia Technology

9th International Conference Interdisciplinarity in Engineering, INTER-ENG 2015, 8-9 October 2015, Tirgu-Mures, Romania

An Assessment of Pollution with Volatile Organic Compounds in the Electric Arc Furnaces

Dana -Adriana Iluţiu - Varvara[a,*], Carmen Maria Mârza[a], Claudiu Aciu[a], Adriana Hădărean[a], Florin Vasile Domniţa[a], Ioana - Monica Sas - Boca[a], Adriana Maria Mihu[a]

[a]*Technical University of Cluj-Napoca, 28 Memorandumului Street, 400114, Cluj-Napoca, Romania*

Abstract

The steelmaking in the electric arc furnace is in the category of the industrial processes with high degree of pollution because in the air environmental factor are transferred the following pollutant substances: volatile organic compounds (VOCs), particulate matter, carbon oxides, sulphur oxides, nitrogen oxides, dioxins and furans. The aim of this paper is to assess the volatile organic compounds (VOCs) emissions from steelmaking in the electric arc furnaces, in order to improve the industrial gaseous emissions management. The experimental researches were carried out on two electric arc furnaces with alkaline lining. The measurement of volatile organic compounds emissions was performed using a Mini Rae Plus Classic device. After evaluating the level of emissions, during the melting stage of charge, it results that the VOCs concentrations from electric arc furnaces depend on the degree of contamination of the charge with organic matter, paints and plastics. The reduction of volatile organic compounds emissions to the steelmaking in the electric arc furnaces may be accomplished by charge component selection and by the use of raw materials with a degree of contamination as low as possible.

Peer-review under responsibility of the “Petru Maior” University of Tirgu Mures, Faculty of Engineering

Keywords: volatile organic compounds (VOCs); electric arc furnaces; industrial emissions; steelmaking, air pollution.

* Corresponding author. Tel.: +40 745 267218.
E-mail address: dana.varvara@gmail.com

Peer-review under responsibility of the “Petru Maior” University of Tirgu Mures, Faculty of Engineering
doi:10.1016/j.protcy.2016.01.086

1. Introduction

Volatile organic compounds (VOCs) incorporate a wide range of carbon-containing compounds that are emitted into the atmosphere from a variety of industrial processes. One of the industrial sources of volatile organic compounds emissions from the ferrous metals industry includes electric arc furnaces [1,2,3,4,5,6,7].

Volatile organic compounds, as defined in EU Directive 2010/75 [8,9], are organic compounds having at 293.15 K a vapour pressure of 0.01 kPa or more, or having a corresponding volatility under the particular conditions of use. Due to their characteristics, the use of VOC solvents in certain installations generates emissions of organic compounds that contribute directly to air pollution and climate change and are also ozone precursors i.e. they react chemically with nitrogen oxides in the presence of sunlight to form ozone. While ozone is beneficial in the upper atmosphere, where it shields the earth from dangerous UV rays, it can be harmful when present in high concentrations at ground level. According to EC Directive 1999/13/EC [10], an organic compound is defined as any compound containing at least the element carbon and one or more of hydrogen, halogens (e.g., chlorine, fluorine or bromine), oxygen, sulphur, phosphorus, silicon, or nitrogen, with the exception of carbon oxides and inorganic carbonates and bicarbonates. An even wider definition is used in the EU National Emissions Ceilings Directive 2001/81/EC [11], where a VOC is any organic compound of anthropogenic nature, other than methane, that is capable of producing photochemical oxidants by reaction with nitrogen oxides in the presence of sunlight.

Volatile organic compounds (VOCs) are of serious environmental concern because of the harmful properties that they exhibit in varying degrees. These include [1,3]:

- direct toxicity to human health;
- contribution to photochemical ozone generation at ground level, with consequent harmful effects;
- destruction of stratospheric ozone;
- contribution to global climate change.

The side effects of the volatile organic compounds on human health can consist of: respiratory system diseases, cardiovascular and gastrointestinal diseases, eyesight problems and skin diseases. Volatile organic compounds are hepatotoxic, nephrotoxic, neurotoxic and carcinogen.

The harmfulness of volatile organic compounds (VOCs) varies greatly, not only because the individual and combined significance of these properties exhibits wide variation between substances, but also it depends on the presence of other substances in the environment. This is related to mass release rate, subsequent dispersion and to its environmental persistence. According to their harmfulness, the volatile organic compounds (VOCs) are divided in the following categories [12,13]:

- extremely hazardous to health (substances such as benzene, vinyl chloride and 1,2 - dichloroethane);
- Class A compounds - those organic compounds that may cause significant harm to the environment (may contribute substantially to photochemical ozone creation or stratospheric ozone destruction or global warming);
- Class B compounds - organic compounds of lower environmental impact than Class A compounds (the remaining majority of VOCs are of lower harmfulness, but whose release must be prevented or minimized).

The potential sources that generate the volatile organic compounds in the steelmaking are: organic matters, paints and plastics from the charge [2]. Sources of volatile organic compounds (VOCs) from electric arc furnaces include [12]:

- scrap preparation with solvent degreasers;
- combusting auxiliary fuel;
- hydrocarbons contained in the oils, wire casing, foam and plastics found in the steel scrap feedstock can vaporize when melting takes place;
- decarburization of scrap;
- charging of the furnace;
- tapping of the molten metal and slag.

The aim of this paper is to assess the volatile organic compounds emissions from steelmaking in the electric arc furnaces, in order to improve the industrial emissions management, by identifying the sources that generates these air pollutants.

The objectives of the paper are:

- the assessment of pollution with volatile organic compounds from electric arc furnace;
- the identification the potential generating sources of VOCs to the steelmaking in the electric arc furnaces;
- establishing methods to reduce the volatile organic compounds to the steelmaking.

2. Material and Method

The experimental researches were carried out on two electric arc furnaces (one with capacity of 10 tons and the other with a capacity of 30 tons) with alkaline lining. The determinations were carried out at a electric steel plant from Alba county, Romania. The type of steel produced in the two furnaces was low alloyed steel. In the Table 1 are presented the chemical composition of steel from which the VOCs emissions were analyzed.

Table 1. Chemical composition of low alloyed steel

Alloying element [%] / Steel type	Si	Mn	Cr	Ni	Mo	V	Ti	W	Co	Al	Cu	Pb	Total
Low alloyed steel	0.5-1.1	0.8-1.8	0.3-0.5	0.3-0.5	0.05-0.1	0.05-0.1	<0.04	0.2-0.3	0.2-0.3	-	-	-	<5

The raw materials used in the steelmaking process from which VOCs originate are old scrap and metallic wastes.

The measurement of volatile organic compounds emissions were performed using a Mini Rae Plus Classic device, every 10 minutes, during the melting technological stage. The resolution of Mini Rae Plus Classic device is 0 - 4000 [ppm]. The melting technological stage had durations of 140 minutes.

3. Results and Discussions

In Fig. 1 are shown a comparison between the average emissions of volatile organic compounds from steelmaking in the two electric arc furnaces.

In Fig. 2 are shown a comparison between the maximum emissions of volatile organic compounds from steelmaking in the two electric arc furnaces.

From the analysis of the data presented in Fig. 1 and 2 results that:

- the average/maximum emissions of volatile organic compounds depend on the quality of charge compositions;
- the average/maximum emissions of volatile organic compounds depend on the degree of contamination with organic matters, paints and plastics of old scrap and metallic wastes;
- the total volatile organic compounds average emissions in the melting stage of the electric arc furnace with capacity of 10 tons were 21834 ppm;
- the total volatile organic compounds average emissions in the melting stage of the electric arc furnace with capacity of 30 tons were 36380 ppm;
- the total volatile organic compounds maximum emissions in the melting stage of the electric arc furnace with capacity of 10 tons were 23368 ppm;
- the total volatile organic compounds maximum emissions in the melting stage of the electric arc furnace with capacity of 30 tons were 38867 ppm;
- the average emissions of volatile organic compounds from electric arc furnace with a capacity of 30 tons are higher by 39.99% when compared to the electric arc furnace with a capacity of 10 tons;
- the maximum emissions of volatile organic compounds from electric arc furnace with a capacity of 30 tons are higher by 39.87% when compared to the electric arc furnace with a capacity of 10 tons;
- at the beginning of melting stage, the emissions of volatile organic compounds register an increase, reaching a maximum concentration of 3012 ppm in the electric arc furnace with a capacity of 10 tons and 3994 ppm for the one having the capacity of 30 tons respectively;

- towards the end of melting, there was a decrease in emissions of volatile organic compounds; the maximum concentration recorded at the electric arc furnace having a capacity of 10 tons was 510 ppm and at the one having the capacity of 30 tons was 586 ppm.

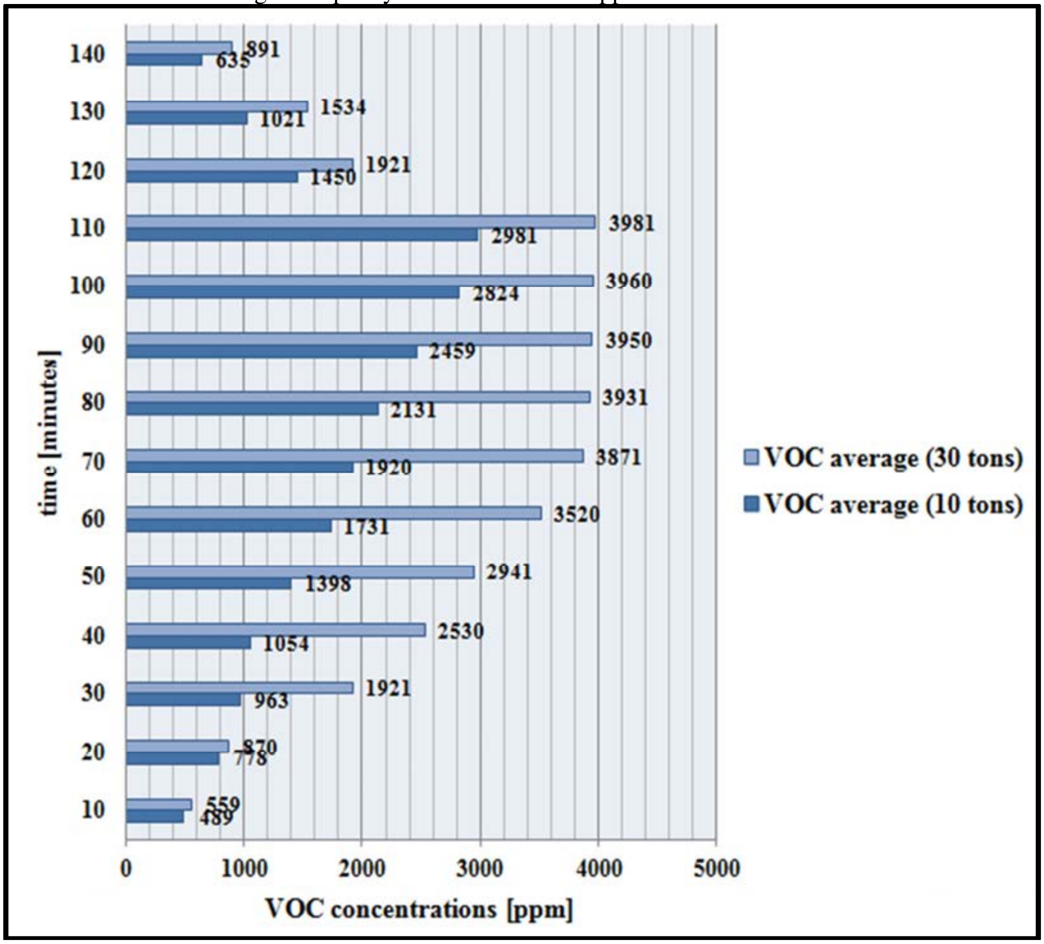

Fig. 1. Comparison between the average emissions of volatile organic compounds from the electric arc furnaces (capacity of 10 tons and 30 tons)

4. Conclusions

From the analysis of the variation volatile organic compounds emissions recorded from the two electric arc furnaces results that the values of concentrations are mainly influenced by the contamination degree of old scrap and metallic wastes.

The average/maximum emissions of volatile organic compounds from electric arc furnace with a capacity of 30 tons are higher by ~40% when compared to the electric arc furnace with a capacity of 10 tons.

Therefore, using air prevention pollution control methods are necessary to reduce the volatile organic compounds emissions from the steelmaking in the electric arc furnace. The reduction of pollution with volatile organic compounds to the steelmaking in the electric arc furnaces is possible by: charge component selection (scrap should be free of dirt, oil and grease); the use of raw materials without organic compounds; scrap management program for the prevention/minimization of potential contaminants in the steel scrap.

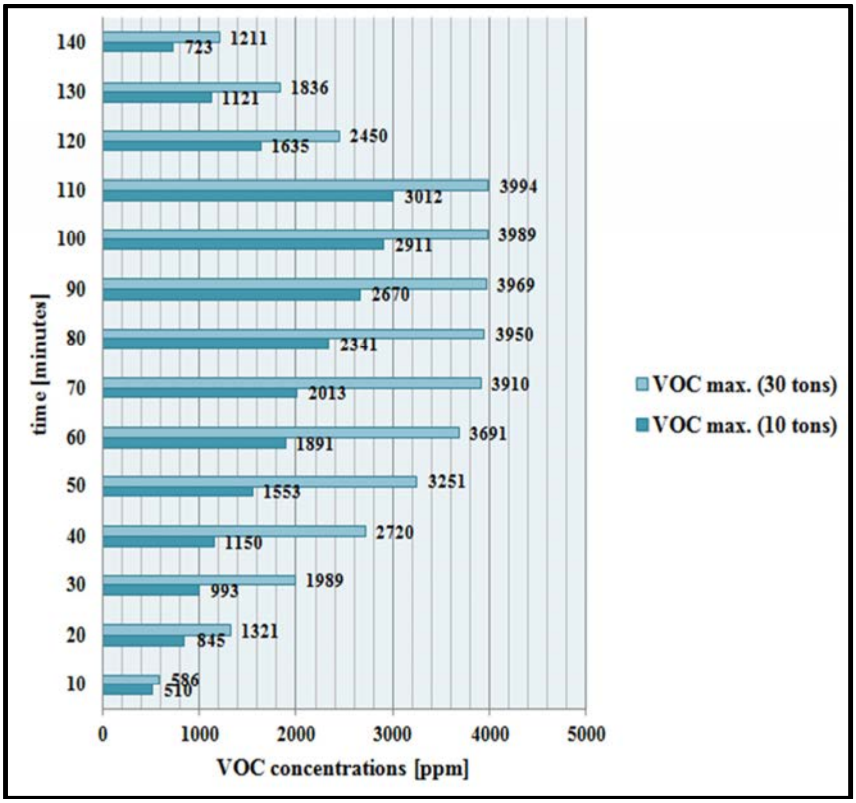

Fig. 2. Comparison between the maximum emissions of volatile organic compounds from the electric arc furnaces having a capacity of 10 tons and 30 tons respectively

References

[1] Iluţiu-Varvara DA. The generation and transfer of pollutant substances in industrial processes, Tehn. Univ. Publishing, Cluj-Napoca, 2007.

[2] Varvara DA. Studies concerning the substances transfer between the steelmaking phases. PhD Thesis, TUC-N, 2007.

[3] Iluţiu – Varvara DA. Experimental researches concerning the volatile organic compounds (VOCs) emissions to the steelmaking. Metalurgia International 2009;7:38-44.

[4] Iluţiu – Varvara DA, Mârza CM, Sas-Boca IM, Ceclan VA. The assessment and reduction of carbon oxides emissions at electric arc furnaces – essential factors for sustainable development. Procedia Technology 2015;19:402-409.

[5] Iluţiu-Varvara DA, Mârza CM, Brânduşan L, Aciu C, Balog A., Cobîrzan N. Assessment of the Metallic Iron Content from Steelmaking Slags in Order to Conserve Natural Resources. Procedia Technology. 2014;12:615–620.

[6] Aciu C, Iluţiu-Varvara DA, Cobirzan N, Balog AA. Recycling of paper waste in the composition of plastering mortars. Procedia Technology 2014; 12:295–300

[7] Cantor (Andreș) DM, Manea DL. Innovative Building Materials Using Agricultural Waste, Procedia Technology 2015;19:456–462.

[8] European Union Directive 2010/75/EU of the European Parliament and the Council of 24 November 2010 on industrial emissions (Integrated Pollution Prevention and Control), Official Journal of the European Union.

[9] Drotloff H. Reduction of emissions by chemical industry from the German emission control act to the Industrial Emission Directive (IED). Procedia Technology 2014;12:637-642.

[10] European Community Directive 1999/13/EC (as amended by Directive 2004/42/CE and Directive 2008/112/EC) on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations.

[11] Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants.

[12] ***Environmental Agency of London. Process subjected to Integrated Pollution Control. IPC Guidance Note, Series 2 (S2), Metal Industry Sector, S2 2.01 Iron and Steel Making Processes, London, 1999.

[13] Fynes G. A review of emissions of volatile organic compounds from industrial processes in the Kings's Lynn Area, EMC Environment Engineering Ltd, Stoke Orchard, Report number C9158, January, 2004.