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SOME CONSIDERATIONS ON INDOOR AND OUTDOOR IMPACTS OF DIFFERENT WAYS OF PM RELEASE AND ODOUR EMISSION IN INDUSTRIAL SECTORS

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Abstract

In the industrial sectors, the ways of release pollutants into the atmosphere can vary significantly. We can find various combinations of primary conveyed emissions, secondary conveyed releases, diffused emissions, depending on the characteristics of the industrial plant. When an environmental impact assessment is performed, discussion concerns mainly the impact on the public health, whilst the occupational impact of these releases is moved to other contexts. The present paper zooms on selected case studies in order to understand the consequences of different way of pollutant release on the outdoor and indoor air quality at the site of the plant (within the fence). Two kinds of pollutants were selected: particulate matter and odoriferous substances. Results demonstrate that the industrial sector is unbalanced: the regulations in force in EU give different attention to the impact of the releases to the atmosphere depending on the industrial sector. In particular, in some sectors the impact of diffused emissions is underestimated because of a raw management of their control. Some preliminary proposals are put forwards for a better management of the emissions to the atmosphere in potentially critical cases. These proposals are based on the concept that conveyed solutions for pollutant release must be preferred, with the care of designing the related stacks with an optimised combination of stack height, conveyed gas velocity, temperature at the exit. The opposition to this approach is basically related to the additional costs. This article demonstrate that these extra-costs are due in many cases. Their economic sustainability is discussed too.

Keywords: *economic sustainability, emissions, impact, industrial, odour, particulate matter*

Introduction

In the European Union (EU), the regulation concerning emissions to the atmosphere from industrial plants evolved during the last decades. The present article wants to contribute to a critical analysis of the reached level, in order to verify which kind of improvements should be studied for guaranteeing a balanced approach. Sometimes the literature has pointed out potential criticalities for specific cases and concerning a variety of pollutants: e.g., unconventional release of PCDD/Fs (Rada et al., 2011) and significant release of NO_x (Ragazzi et al., 2015), both at outdoor level. Sometimes the criticalities concern indoor conditions that could affect the attention at occupational level, when talking about CO₂ accumulation (Ragazzi et al., 2017).

In the case of the present article, the interest is towards the ways of release pollutants into the atmosphere, as they can vary significantly. When zooming on the environmental impact of the concerned plants, the discussion refers mainly on the impact on the public health, whilst the occupational impact of the related emissions is moved to other contexts. The present paper zooms first on selected case studies developed with the participation of the Author. The aim is to understand the consequences of different way of pollutant release on the outdoor and indoor air quality at the site of the plants (thus, also within their fence). Two pollutants were selected: particulate matter (PM) and odour (odoriferous substances). Both of them are a mix of compounds that can affect the human health or the human wellbeing both in the short and in the long term. The discussion, presented together with the results, wants to contribute to an enhancement of the approach of emission control, taking into account some potential criticalities that concern not only the population exposure but also the occupational one.

Materials and Methods

The pollutants selected for this article (particulate matter and odour) are topical in the frame of the international literature. Indeed, their relevance is demonstrated by the growing yearly production of related articles in the Scopus® database, in the last decade.

The methodology adopted in the present article is the following:

- ◆ classify the main ways of release of pollutants into the atmosphere, in industrial plants;
- ◆ find industrial activities that could have potential criticalities (both on the territory and at occupational level) in releasing pollutants by those modalities, specifically for particulate matter and odour;
- ◆ find literature that allows zooming on those criticalities;
- ◆ discuss about technical solutions to decrease the impact on environment and health; valorise existing methodologies and studies for a first quantification of the effects of those solutions, when this is needed;
- ◆ discuss about the sustainability of the costs for implementing those solutions.

As reported above, the literature analysis and the discussion start from the scientific production of the Author to be enlarged to the literature of the sector in order to verify if the criticalities pointed out have reached a common point of view.

Results and Discussion

Looking at the typical industrial activities, often they show three kinds of options, alone or in combination, to release pollutants into the atmosphere, in a context of EU authorisation:

- ◆ release of off-gas from a main stack;
- ◆ release of emissions, both conveyed (into secondary stacks) and areal (e.g. from a biofilter) that are considered having a lower impact;
- ◆ evacuation of indoor air from sections of the plant where pollutants are generated from secondary activities.

Among the wide variety of industrial activities that are authorised in the EU, four of them were selected for the analysis reported in the present article:

- ◆ **bio-drying** of residual municipal solid waste (RMSW); this process (Rada et al., 2012; Velis et al 2009) aims to modify the characteristics of the MSW that remains as result of the activation of selective collection (SC), that is the RMSW; the performed modifications allow an easier post-treatment to extract non-combustible recyclable materials (glass, metals, inert) in order to generate a fuel that can substitute coal in a few industrial plants; often (e.g. in Italy) the process air is treated and released from a biofilter;
- ◆ **composting** of source separated food waste (Cadena et al., 2009); this process aims to valorise source separated food waste in order to generate a product (compost) to be used on agricultural lands; also in this case the treated process air is typically released from a biofilter; however, the potential criticalities are different from the case of bio-drying because the amount of putrescible volatile solids consumed per unit of input are higher in case of composting. Thus, composting can have a higher impact in terms of odour;
- ◆ **RMSW incineration** (Thorin 2012); in this case the aim is the generation of energy from the valorisation of the fractions of MSW that are not suitable for material recycling (in the virtuous contexts where selective collection has been optimised); typically, the pollutant releases are from primary and secondary stacks.
- ◆ **Steel making plants** (Tupkary 2017); the technology for producing steel can vary a lot in the sector; in the present article, the case of electric arc furnaces is analysed, focusing on the variety of releases into the atmosphere that characterise these plants.

These activities cover all the modalities of release to the atmosphere listed above. Two of them are based on biological processes at low temperature; the remaining two are high temperature processes.

The potential criticalities (both on the territory and at occupational level) that characterise the above-mentioned activities concern many kinds of pollutants. The present article focuses on particulate matter and odour, as explained below:

- ◆ **bio-drying** is based on a strong aeration of the RMSW; thus, one of the potential criticalities is related to the extraction of particulate matter from the biological reactor through the evacuation of the exhausted air; the common adoption of a biofilter to decrease the pollutants loads generates an areal release at low height, low velocity, low temperature, thus low dilution into the atmosphere; the verifications of the consequent impact are related typically to the impact on the territory; in the present article, the effects of the accumulation of particulate matter in the area of the plant are discussed also in terms of impact on the workers, that could be underestimated;
- ◆ also **composting** is based on a strong aeration; in this case the aeration concerns food waste; in this sector, it is well known that the main criticality is related to the generation of odour mostly from the biological reactor; again, the typical adoption of a biofilter to decrease the pollutants loads generates an areal release at low height, low velocity, low temperature, thus low dilution into the atmosphere; again, the impact is typically studied in terms of effects on the territory; in the present article,

the impact of odours in the area of the plant are discussed also in terms of exposure of the workers, as this aspect could be underestimated;

- ◆ **RMSW incineration** is widely studied in terms of environmental and health impact on the territory; these analyses helped to modify the characteristics of the process and to favour its evolution in the last decades. However, today the main concern is the main stack and its role in the pollutants impact. In the present article, some aspects both on particulate matter and odour are discussed in terms of workers' exposure;
- ◆ **steel making plants** are widely studied too, because of the fate of the pollutants already present in the input, because of the high flowrate sent to the main stack after treatment, because of the potential process stage where the roof of the plant is open and, finally, because of the evacuation of air (polluted) from the windows of the industrial building. In the present article, some considerations on particulate matter are discussed in terms of workers' exposure.

The literature selected as a starting point to zoom on the above-mentioned criticalities is the following:

- ◆ **RMSW bio-drying**: here the quantification of the phenomena can be made adapting an approach available in the literature for a case study (Rada & Ragazzi 2011). If we assume, as first approximation, that the released particulate matter from the biofilter of the case study has a diffusive behaviour similar to a gas and if we use an emitted particulate matter concentration equal to 5 mg/m^3 , results show that only at a few hundreds of meters from the plant the concentration decreases of one order of magnitude. Apart from the non-negligible incidence of dust on the territory, the reduced dispersion causes an accumulation of dust that can be relevant for the workers' exposure. In practice, the workers operate in a deformed half-bubble of pollutants locally accumulated (deformation depends on the wind). The fact that the particulate matter has a granulometry that gives a behaviour only partially equivalent to a gas means that the highest granulometric classes tend to settle closer to the plant, increasing the relevance of the phenomenon;
- ◆ **food waste composting**: the quantification of the phenomena can be based on an approach available in the literature (Rada & Ragazzi 2013). conventional biofilters are authorised in EU with emission odour units in a range typically around $250\text{-}300 \text{ o.u./m}^3$. The cited case-study demonstrates that the impact of the odorigenous emissions of a conventional biofilter could be negligible only at more than 1 km from the plant. Again, apart from the non-negligible incidence of odours on the territory, the reduced dispersion accumulates the odorigenous compounds at levels that can be relevant for the workers' exposure. Again, the workers operate in a deformed half-bubble of compounds locally accumulated, with uncomfortable conditions of work;
- ◆ **RMSW incineration**: a first quantification of the phenomena can be based on an approach available in the literature (Schiavon et al., 2019). Secondary emissions of particulate matter from an incinerator are typically authorised without analysing their incidence at ground level. On the contrary, the less stringent emission limits for secondary sources and their

lower height of emission can give a contribution of dust at ground level that can be higher than the one from the main stack, as demonstrated in the cited study (the impact of the secondary contributions are double than the one from the main stack, in that case). Another anomaly can come from the authorisation of the release of odorigenous compounds when the incineration activities are stopped for maintenance and the waste pit is full: the air extracted from the building of the pit is typically sent to combustion, but this is the case of maintenance with no combustion performed. In this case, a simple deodorisation system (e.g. activated carbon filters) with low height release could be critical, creating at least discomfort among the staff working at the plant;

- ◆ **steel making plants:** a first quantification of the phenomena can be based on studies concerning not only the modelling of the pollutant diffusion to the atmosphere, but also the use of deposimeters and soil characterisation (Rada et al., 2016a; Rada et al., 2016b). This mixed approach comes from the need to verify the role of secondary and diffused emissions that can be significant for conventional plants. Zooming on the selected case, results show that the role of the main stack is expected to have a negligible effect on the territory, including the internal area of the plant; however, a remark must be done on the way of managing the authorisation to the release of heavy metals, as the limit to be complied with at the stack is a generic sum of concentrations, not dependent on the single toxicity of the heavy metals. On the contrary, in a conventional plant, secondary and diffused emissions are expected to create a deformed half-bubble of pollutants, including particulate matter, that can affect the quality of the air within the gate of the plant and for hundreds of meters in the surroundings.

For each of the selected criticalities, the technical sector offers solutions that mitigate the problems pointed out, as explained below:

- ◆ in case of **RMSW bio-drying**, two options can be comparatively analysed starting from a methodology described in literature (Ragazzi et al., 2014); the comparison can be made in terms of positioning of the conventional biofilter: on the ground vs on the roof of the plant there described. Calculations have been regenerated for the present article considering a concentration of particulate matter after biofiltration (assumed as a first approximation as having a behaviour of a gas) equal to 2.5 mg/m^3 ; results showed a significant decrease (up to 5 times) of dust deposition in the area within the gate of the plant and in the closest surroundings; thus, the "roof option" gives a contribution to protect the workers operating at the plant. More technological solutions are potentially available; they are discussed in the next section, related to composting, because of some similarities;
- ◆ **food waste composting** is evolving towards anaerobic digestion plus post-composting, specifically in countries where the generation of electricity from renewable sources receives public incentives; if this is the case, the odorigenous impact is reduced thanks to the introduction of the sealed reactor of anaerobic digestion; if the approach of direct composting must be confirmed, a solution different from what discussed above for bio-drying could be the introduction of an additional exhaust air treatment step as non-thermal plasma (Schiavon et al., 2015) to decrease the odorigenous

load reaching the biofilter; however, also in this case the adoption of an open biofilter on the roof of the plant can reduce the incidence of the plant locally; a solution alternative to biofiltering, named biotrickling filter, is expected to enlarge the viable options but it is not yet optimized for a real scale in the composting sector. Based on a compact bioreactor, the exhausted air after treatment is conveyed at a stack guaranteeing a good pollutant dilution into the atmosphere (Schiavon et al., 2016). Another conveyed system, named regenerative thermal oxidation (RTO) is already available in real scale, but it is based on the controversial use of methane to get high temperature (before heat recovery) to thermally oxidize the undesired compounds (Rada & Ragazzi, 2011). Non-thermal plasma, biotrickling filter and RTO can be of interest not only for composting but also for RMSW bio-drying;

- ◆ As pointed out above, in the sector of *RMSW incineration* there is a need to pay more attention to the role of secondary emissions. Designing/modifying the height of release of these emissions can give important results in terms of reduction of the internal impact in the area of the plant. It must be also remembered that indoor air in the office section is affected by the outdoor air quality, thus advantages can be obtained also for the staff of the plant;

A solution to prevent RMSW incineration to give odour problem when combustion is not performed for plant maintenance, but the waste pit is full, is the adoption of a fan to force the contaminated air of the pit to exit through the main stack. Its height guarantees generally some orders of magnitude of dilution;

- ◆ *steel making plants* are complex infrastructures; in spite of that, an important solution to decrease their impact, when not yet performed, is conceptually simple: maximise the conveying and treatment of polluted streams before their release into the atmosphere in order to increase the dilution effect. Low height releases must be avoided. Moreover, conveying makes easier a correct monitoring of discharged flowrates and concentrations.

The considerations reported above demonstrate that the incidence of the underlined criticalities on the impact of the plants could be not negligible. In spite of that, the solutions presented above are not considered compulsory neither for authorisation pathways nor in most of the literature of the sector (e.g., referring to the Scopus® database). An explanation could be the extra-costs for their implementation. To this concern, some considerations can be made:

- ◆ In the sector of MSW, many tenders are based on criteria that ask to choose the cheapest offer; that causes a cut of all not specifically requested from the regulation in force; a bonus in the evaluation of the offers showing more attention to the health of population and workers, beyond the regulation in force, should be included;
- ◆ When the initiative for the construction of a plant is totally private, it is the authorisation pathway that must guarantee and enhanced approach in the prevention of effects on health and environment. Thus, the presence in EU of plants that can release pollutants in non-conveyed (cheap) conditions means that a lot must be done yet for having really modern regulations.

Conclusions

The present article analysed two industrial activities at low temperature and two at high temperature. Results showed that some local impact criticalities in terms of particulate matter and odour are not temperature depending. The central role belongs to the modality of release: conveyed or diffused. Moreover, secondary emissions could be underestimated when the attention is fully concentrated on the main stack of a plant. Some potential criticalities have been found also thanks to an analysis of the literature of the sector, adapted to the new vision of the impact proposed in the present article: workers, and staff in general, operate on the site; thus, plant designs and authorisations should avoid solutions that accumulate pollutants within the gate of the plants. In some cases, the technical options available in the sector have to complete their evolution to the real scale; however, the most important solution to mitigate the impact of the analysed cases is based on emissions adequately conveyed to a stack. Of course, the modifications could be expensive, but talking about health of population and workers, the criteria to consider economically sustainable a solution should be seen with more attention to protect.

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