Life cycle assessment of pig rearing with wet acid scrubber for ammonia emissions reduction

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Introduction

Air inside pig barns is characterized by either high concentration of ammonia (NH3) and particulate matter (PM) that can pose a direct hazard to animals and workers health, or odors (VOCs). The same poor-quality air is released into the environment, causing odor nuisance and atmospheric pollution in the surrounding rural and urban areas. It is well known that the agricultural sector is mainly responsible for NH3 emissions, arising principally from manure management and from fertilizers application. Released into the environment, NH_3 causes soil acidification, nutrient-N enrichment of ecosystems, and terrestrial eutrophication. Furthermore, NH_3 is a chemically active gas able in the atmosphere to react with sulfuric and nitric acids to form secondary inorganic PM (PM2.5). PM2.5 is a threat to human health, several epidemiological studies show a causal link between PM exposure and cardiovascular and respiratory system damages. According to Kiesewetter et al. (2015) in the Po valley it leads to a reduction in life expectancy of about 36 months. Po Valley is one of the European regions with the highest levels of PM due to the concurrent high density of anthropogenic sources and its orographic and meteorological characteristics unfavorable for pollutant dispersion. In particular, Lombardy region is located in the middle of the Po basin and it presents the highest Italian pig population density, accounting for more than 4 million heads. Different strategies are available to reduce NH_3 emissions from pig housing: feeding strategies, slurry storage, treatment and application techniques, and air cleaning systems.

The LIFE-MEGA project (LIFE18 ENV/IT/000200) aims to reduce NH_3 and PM emissions from piggeries, with a benefit for human health in rural and urban air quality. The project aims to develop and test in pig houses, located in the Lombardy region, two different abatement systems (dry and wet scrubber). The dry scrubber is a technology already used in other industrial contexts (e.g., baking), whereas the wet scrubber will be a prototype using citric acid. This study reports the results in terms of environmental impact reduction using the wet acid scrubber.

Material and methods

The aim of the present study was to provide an initial assessment of the environmental impact of an Italian farm producing heavy pigs where a wet acid scrubber for air treatment was installed. The functional unit selected was 1 kg of pig live weight (LW) at the farm gate. Two alternative scenarios were considered: the baseline scenario (BS) representing the situation as it is, and the alternative scenario (AS) where the wet acid scrubber prototype (with 60% NH_3 removal efficiency) was adopted. Regarding the system boundary, a “cradle to farm gate” approach was applied, including all inputs (e.g., machinery, fuel, lubricant, organic and mineral fertilizers, pesticides, water, off farm feed) and outputs (emissions to air, soil and water).

The case farm was an intensive farrowing to finishing farm, producing heavy pigs for traditional dry-cured hams, located in the province of Brescia (Italy). A farrow-to-finish system comprises all phases of pig production, from the farrowing phase to produce piglets till the growing-finishing one where pigs are raised till market weight (for dry-cured ham PDO disciplinary, minimum 160 kg LW at slaughter). The agricultural area of the farm was 100 ha, entirely used for maize grain production. Primary data were collected during surveys on farm carried out by experts by asking for information about: herd management, field production, feeding, and slurry management. Data related to the wet acid scrubber prototype were provided by the construction company.

As concern secondary data, CH_4 and N_2O emissions were estimated according to the IPCC guidelines (IPCC, 2019), whereas EEA guidelines (EEA, 2019) were used for NH3 ones. Finally, background data concerning the production of the different inputs (e.g., seeds, pesticides, fertilizers, diesel, tractors and implements) were retrieved from the Ecoinvent Database v.3 (Weidema et al., 2013).

Twelve environmental impacts were evaluated: Climate Change (CC), Ozone Depletion (OD), Human toxicity, non-cancer effects (HTnoc), Human toxicity, cancer effects (HTc), Particulate matter (PM), Photochemical ozone formation (POF), Acidification (TA), Terrestrial eutrophication (TE). Freshwater eutrophication (FE), Marine eutrophication (ME), Freshwater ecotoxicity (FEx) and Mineral, fossil & renewable resource depletion (MFRD).

Results and Conclusion

Table 2 shows the environmental impacts of 1 kg of pig LW for the two scenarios analyzed. Besides the absolute values for the different impact categories, it is reported also the variation between BS and AS calculated as: (Impact of AS – Impact of BS)/Impact of BS.

For 8 of the 12 evaluated impact categories, AS shows higher impact respect to BS, due to the impact associated with the wet acid scrubber construction and maintenance. The best solution depends on the selected impact

category. Indeed, the AS was the best the impact categories influenced by NH3 emissions (PM, TA, TE, and ME), for which a reduction of 2% (PM), 8% (TA), 9% (TE), and 0.2% (ME) was observed. The climate change impact was 3.55 kg CO2 eq/kg LW and 3.65 kg CO2 eq/kg LW for BS and AS, respectively, aligning with Bava et al. (2017) and González-García et al. (2015) results. The scrubber affects positively the impact categories influenced by the ammonia emissions while increase the impact of the other impact categories and of MFRD.
Regardless of the scenario considered, feed production was the main hotspot in all impact categories and of heavy pig production. In the farm analyzed, only maize grain is partially produced on-farm, instead all other feed ingredients are purchased. As an example, the replacement of soybean imported from South America with protein sources locally produced certainly could affect the final impact (Bava et al. 2017). Moreover, also the use of precision feeding systems in growing and finishing phase could help in reducing the environmental impact of pig production. CH_4 emissions significantly affect CC (50% and 48% in BS and AS, respectively). After feed, NH_3 emissions are the main responsible for PM, TA and TE impact share, ranging from 34% to 45% for BS and from 26% to 37% for AS. As expected, in AS NH_3-related impacts are less than in BS. Electricity is responsible for a share ranging from 0.2% to 4.9% for all the evaluated impact categories. Regarding the wet scrubber contribution to the environmental impact of 1 kg of pig LW at the farm gate, in AS it registers the highest relative contribution for MFRD (50%) and the lowest for TE (0.6%). A reduction of the scrubber impact could be achieved substituting the source of the electricity consumed (e.g., by installing a photovoltaic panel on the roof of stables). Even if not specifically foreseen in the Life MEGA project the use of renewable energy to feed the scrubber would probably improve its environmental performances.

Table 2. Absolute environmental impacts for the baseline (BS) and alternative (AS) scenario

Impact category	Unit	BS	AS	Δ (%)
CC	kg CO_2 eq	3.55	3.65	2.81%
OD	CFC^{-11} eq · 10^{-7}	3.12	3.32	6.53%
HTnoc	CTUh · 10^{-7}	7.08	7.29	3.00%
HTc	CTUh · 10^{-8}	1.90	2.24	17.45%
PM	kg $PM_{2.5}$ eq · 10^{-3}	3.28	3.16	-3.62%
POF	kg NMVOC eq · 10^{-2}	1.08	1.13	4.66%
TA	molc H+ eq	0.12	0.10	-10.16%
TE	molc N eq	0.51	0.46	-10.98%
FE	kg P eq · 10^{-4}	4.49	4.65	3.57%
ME	kg N eq · 10^{-2}	1.93	1.92	-0.36%
FEx	CTUe	23.74	23.95	0.91%
MFRD	kg Sb eq · 10^{-5}	2.42	4.88	101.84%

Abstract review

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