Furnace injection of dolomitic sorbent as retrofitting option for HCl and SO2 removal in waste-to-energy plants

Alessandro Dal Pozzo[1], Giacomo Antonioni[1], Valerio Cozzani[1]

[1]Department of Civil, Chemical, Environmental and Materials Engineering, Alma Mater Studiorum – Università di Bologna, via Terracini 28, 40131 Bologna, Italy
Keywords: waste-to-energy; flue gas treatment; acid gas removal; furnace injection
Presenting author email: a.dalpozzo@unibo.it

Acid gases like HCl and SO_2 are typical pollutants arising from the combustion of municipal or industrial waste fractions having Cl and S content. Among all the macro-pollutants released by waste combustion, acid gases present the lowest emission standards in EU, USA and China. In Europe, particularly, the upcoming revision of the BAT (Best Available Techniques) for waste incineration sets high standards for the emission control of these contaminants (European IPPC Bureau, 2019). Existing waste-to-energy (WtE) plants might require retrofitting of their acid gas treatment systems to achieve the high removal efficiency indicated by the BAT revision and, thus, to obtain a renewal of their environmental permits.

In that regard, furnace sorbent injection (FSI), *i.e.* the direct injection in the combustion chamber of the plant of a solid reactant that can capture acid pollutants via gas-solid reaction, can be a simple approach to retrofitting, with minimal investment cost and without the need for additional equipment (Miller, 2017). In particular, powdered sorbents derived from dolomite rock have been recently proposed as suitable reactants for FSI applications (Biganzoli *et al*, 2015), because the presence of magnesium confers them a higher resistance to high-temperature sintering compared to calcium-based sorbents and limits the clogging and fouling that the deposition of calcium-based residues and fly ash typically produces on boiler surfaces (Moreschi and Marras, 2014).

The current study had the aim of collecting quantitative information on the performance of acid gas removal by dolomitic sorbent direct furnace injection, in order to derive a relationship between reactant feed rate and acid gas removal efficiency. The effectiveness of reactant injection towards HCl and SO_2 was systematically investigated by full-scale test runs conducted in two Italian WtE facilities.

Both plants adopted the injection of sodium bicarbonate at low temperature (180 °C) as acid gas abatement stage, as commonly performed in several European WtE plants (Dal Pozzo *et al*, 2018). As sketched in Fig. 1a, the tested configuration consisted in the introduction of the dolomitic sorbent as an additional acid gas abatement stage directly in the combustion chamber (T ~ 1000 °C).

The concentration of HCl and SO_2 in the flue gas was measured downstream of the furnace (point SMP). Therefore, in order to assess the effect of dolomitic sorbent injection on the acid pollutants, "on/off tests" were performed by alternating periods of injection and interruption of the reactant feed rate, as shown in Fig. 1b. The removal efficiency of the sorbent towards HCl or SO_2 at different feed rates was calculated considering the reduction in acid gas concentration at point SMP compared to the periods without injection of reactant. The experimental data extracted with this test run procedure were then used to calibrate a previously formulated operational model for dry acid gas removal (Dal Pozzo *et al*, 2016), linking the feed rate of reactant and the corresponding HCl and SO_2 conversion.

The results of the test run campaign are summarized in Fig. 3c, where the acid gas removal efficiency (for HCl and for SO_2) is plotted as a function of the stoichiometric ratio (SR) of reactant. SR is defined as the ratio of the actual feed rate of reactant to the theoretical chemical neutralisation demand, *i.e.* the amount of reactant theoretically required to convert all the acid pollutants present in the flue gas (Vehlow, 2015). Dolomite appeared particularly reactive towards SO_2: at SR = 1 (i.e. reactant feed rate without stoichiometric excess), the removal efficiency for SO_2 and HCl was 81 % and 29 %, respectively.

Calibrating a performance model (continuous lines in Fig. 1c) on the experimental data (dots) allowed assessing the cost-effectiveness of the introduction of a furnace injection of dolomitic sorbent and identifying the optimal feed rate of dolomitic sorbent for a WtE plant already equipped with a bicarbonate stage of acid gas removal. The optimal feed rate of dolomitic sorbent is the feed rate that minimises the overall operating costs of the acid gas treatment line, keeping constant the overall acid gas removal efficiency.

To study the optimization of the two-stage acid gas removal system (dolomitic sorbent stage + bicarbonate stage), the calibrated model was used to simulate the operation of the WtE acid gas removal line (furnace injection of dolomitic sorbent + downstream bicarbonate injection) at different feed rates of dolomitic sorbent. Typical acid gas concentrations (HCl = 1000 mg/Nm^3, SO_2 = 200 mg/Nm^3) resulting from municipal waste combustion were considered as reference case for the flue gas composition entering the treatment system. The overall operating costs of the two-stage line (cost of the reactants plus disposal of process residues) were assessed as a function of HCl conversion in the dolomitic sorbent stage, as shown in Fig. 1d, while keeping constant the overall acid gas conversion in the two-stage system. The minimum of operating costs was found for a 25 % HCl conversion in the dolomitic sorbent stage, which realizes a 14 % cost reduction compared to the single-stage sodium bicarbonate acid gas removal system without furnace dolomite injection.

To sum up, the present study, based on a full-scale campaign, carried out a first, systematic assessment of the effectiveness of adding furnace sorbent injection to different flue gas treatment processes, establishing a quantitative correlation between feed rate of reactant and resulting HCl/SO_2 conversion. The results of the test run campaign demonstrated the cost-effectiveness of acid gas removal via the high temperature reaction with dolomitic sorbent. Retrofitting a plant equipped with a sodium bicarbonate treatment stage with an additional dolomite stage as furnace injection can reduce the overall operating cost of acid gas treatment, if the feed rate of dolomitic sorbent is properly optimized.

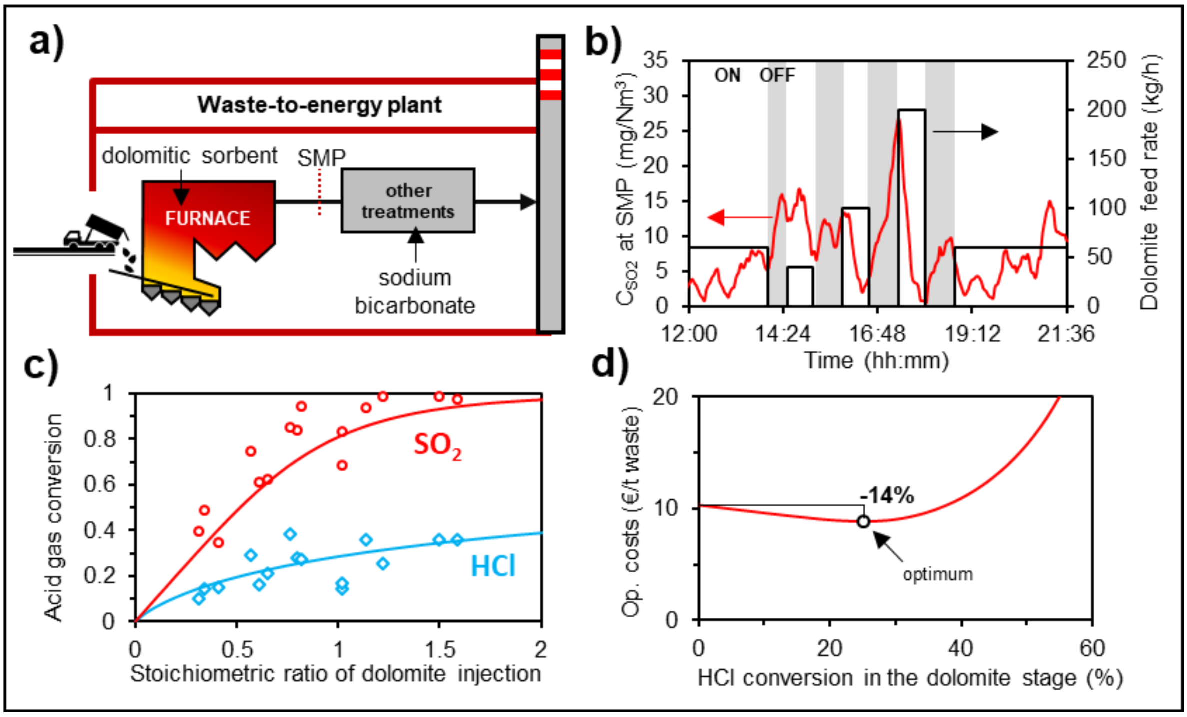

Figure 1. Framework of the study: a) sketch of the WtE plant configuration (dolomitic sorbent injection + bicarbonate two-stage acid gas removal system); b) dolomite feed rate and SO_2 concentration over time during a typical test run; c) removal efficiency of calcined dolomite for HCl and SO_2; d) operating costs of the two-stage acid gas removal system as a function of HCl conversion in the dolomite stage.

References

Biganzoli, L., Racanella, G., Rigamonti, L., Marras, R., Grosso, M., 2015a. High temperature abatement of acid gases from waste incineration. Part I: Experimental tests in full scale plants. *Waste Manage.* 36, 98-105.

Dal Pozzo, A., Antonioni, G., Guglielmi, D., Stramigioli, C., Cozzani, V., 2016. Comparison of alternative flue gas dry treatment technologies in waste-to-energy processes. *Waste Manage.* 51, 81-90.

Dal Pozzo, A., Guglielmi, D., Antonioni, G., Tugnoli, A., 2018. Environmental and economic performance assessment of alternative acid gas removal technologies for waste-to-energy plants. Sustainable Prod. Consumption 16, 202-215.

European IPPC Bureau, 2019. Best Available Techniques (BAT) Reference Document for Waste Incineration. Available at: https://eippcb.jrc.ec.europa.eu/sites/default/files/2020-01/JRC118637_WI_Bref_2019_published_0.pdf (last accessed: 18/11/2019).

B.G. Miller, Formation and Control of Sulfur Oxides, in: Clean Coal Engineering Technology. 2nd ed. Oxford: Butterworth-Heinemann, 2017, pp 467-506.

Moreschi, R., Marras, R., 2014. International patent n° WO/2014/080373. Available at: https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2014080373&tab=PCTBIBLIO (accessed 03/09/2019).

Vehlow, J., 2015. Air pollution control systems in WtE units: An overview. *Waste Manage.* 37, 58-74.