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Safety issues related to the maintenance operations in a vegetable oil refinery: A case study

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ABSTRACT

The present work was focused on maintenance hazards related to vegetable oil refining. An incident occurred in an Italian vegetable oil refinery was presented to evidence this safety criticality. The incident took place during a maintenance shut down, and was associated to the ignition of the solid residual in a packed column. No fatalities or injuries were reported, but the column was strongly damaged and removed from the plant. A specific experimental characterization of the solid residues accumulated in the column, sampled both from the damaged and undamaged parts of the column, was carried out in order to determine the conditions leading to unwanted combustion of the residues. At the same time, samples taken from the damaged column steelwork were subjected to metallurgical analysis aimed at the thermal and mechanical characterization of the steel, obtaining information about the incident duration and temperature reached during the combustion phenomenon. The study evidenced the need of adequate maintenance procedures and safety management in the generic framework of food industry, identified as key lessons learned.

1. Introduction

An increase of the edible oil industrial production by seed extraction is expected in the next years due to its growing consumption and request (FAO, 2013). Therefore, a wider diffusion of industrial facilities for vegetable oil processing and refining will consequently occur, also close to residential areas.

A critical phase of the edible oil production chain is the final refining aimed at removing free fatty acids, which, in too high concentrations, may cause the rancidity of the oil (Akterian, 2011; Bhosle & Subramanian, 2005; Calliauw et al., 2008; Carmona, Jiménez, Jiménez-Sanchidrián, Peña, & Ruiz, 2010; Cavanagh, 1976; Cuevas, Rodrigues, & Meirelles, 2009; Keurentjes, Doornbusch, & Van't Riet, 1991; Martinello, Hecker, & Pramparo, 2007; Sullivan, 1976), and other minor components such as phospholipids, pigments, proteins, oxidation products and the possible residual content of the solvent used for the extraction process. This stage of the production chain is crucial for the quality enhancement of the final product. Despite the extremely limited amount of hazardous substances in this type of facilities, safety and environmental criticalities associated to the refining process were discussed in previous works (Landucci, Nucci, Pelagagge, & Nicolella, 2011, Landucci, Pannocchia, Pelagagge, & Nicolella, 2013). In particular, the possibility of accidental combustion associated to the accumulation of the extraction solvent (typically hexane) was discussed, also considering the recent accidents occurred in Italy (La Repubblica, 2006) and Spain (El Economista, 2007), that caused several fatalities among maintenance operators.

Another potential safety issue associated to maintenance operations in vegetable oil refining plants is related to the accumulation of unwanted solid residuals downstream the chemical treatment of the crude vegetable oil, which consists of degumming, neutralization, washing, drying and bleaching (Gunstone, Harwood, & Padley, 1994; Loft, 1990; Mag, 1990; Santori, Di Nicola, Moglie, & Polonara, 2012; Shahidi, 2005). In particular, in this latter treatment, bleaching earths and activated carbon are mixed with the oil in order to remove pigments; next, the slurry is filtered obtaining a liquid phase which is further processed in the deodorization. This operation consists of high temperature steam stripping in a packed column. This stage is aimed at removing the residual acid compounds at low pressure (2 mbar) and high temperature (200–250 °C). For prolonged periods of operations or due to poor

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maintenance, residuals of filtration may accumulate in the column packing causing loss of efficiencies (pressure drops and non-uniform liquid distribution) and generating potentially hazardous situations (Kister, 2003). In particular, it is well known that in case combustible material residuals are distributed on column packing or, more in general, in equipment internals, one of the hazards is related to the possible auto-ignition (Davie, Mores, Nolan, & Hoban, 1993; Plellis-Tsaltakis, 2012); in some cases, parts of metal structured packing may ignite, heating the equipment wall to temperatures able to compromise the structural integrity of the process equipment (Ender & Laird, 2003; Mannan, 2003; Roberts, Rogers, Mannan, & Ostrowski, 2003).

In the present work, an incident occurred in an industrial vegetable oil refinery at the deodorization column is presented to evidence this safety criticality in a process in which no combustible materials were expected to accumulate and cause hazardous situations. The incident took place in the night between September 26th and 27th 2012, during a maintenance shut down. A fire was generated by the auto-ignition of the solid residuals in the column packing. No fatalities or injuries were reported, but the column was strongly damaged and removed from the plant.

A specific experimental characterization of the solid residual, sampled both from the damaged and undamaged parts of the column, was carried out in order to reproduce the column internal conditions at the moment of the incident and to verify the possibility of auto-ignition of the residual. On the same time, steel samples taken from the column wall, both from the damaged and undamaged parts, were subjected to metallographic and hardness analysis. Moreover, samples collected from the undamaged parts of the column were heat treated at different times and temperatures and their microstructure and hardness were compared with that of the damaged parts in order to obtain information about the incident duration and temperature reached during the combustion phenomenon.

2. Description of the incident

The incident occurred in the deodorization column of SALOV S.p.A. refinery during the night between September 26th and 27th 2012. The refinery is located in Massarosa (Italy), between vulnerable residential areas of Viareggio and Massarosa as shown in Fig. 1a.

The facility, which covers a total surface of about 100,000 m^2 and features an overall storage capacity of 8500 tons, produces 1.3×10^5 m^3 per year of different oil types.

A schematic representation of the process is shown in Fig. 1b, in which the available instrumentation is also reported. A summary of the features of the column and column accessories is reported in Table 1.

On September 26th, the unit was removed from service following a specific SALOV procedure, which consisted in closing the heating steam feed and waiting till the temperature, measured by the indicator shown in Fig. 1b, reached 80 °C. After the shut down, a maintenance operation was scheduled on the liquid level transducers (see Fig. 1b). During the afternoon of the same day, the maintenance operators removed the mentioned instrumentation opening the column to the atmosphere without a preliminary nitrogen blanketing, not requested by the shut down procedure due to the absence of any hazardous substance in normal conditions. At 8:00 pm, both the maintenance and process operators left the plant.

When the morning shift of September 27th started (7:00 am), no significant change in the column operating parameters was observed. In particular, data recorded by the available instruments (see Fig. 1b) showed 1.01 bar pressure and 32 °C temperature.

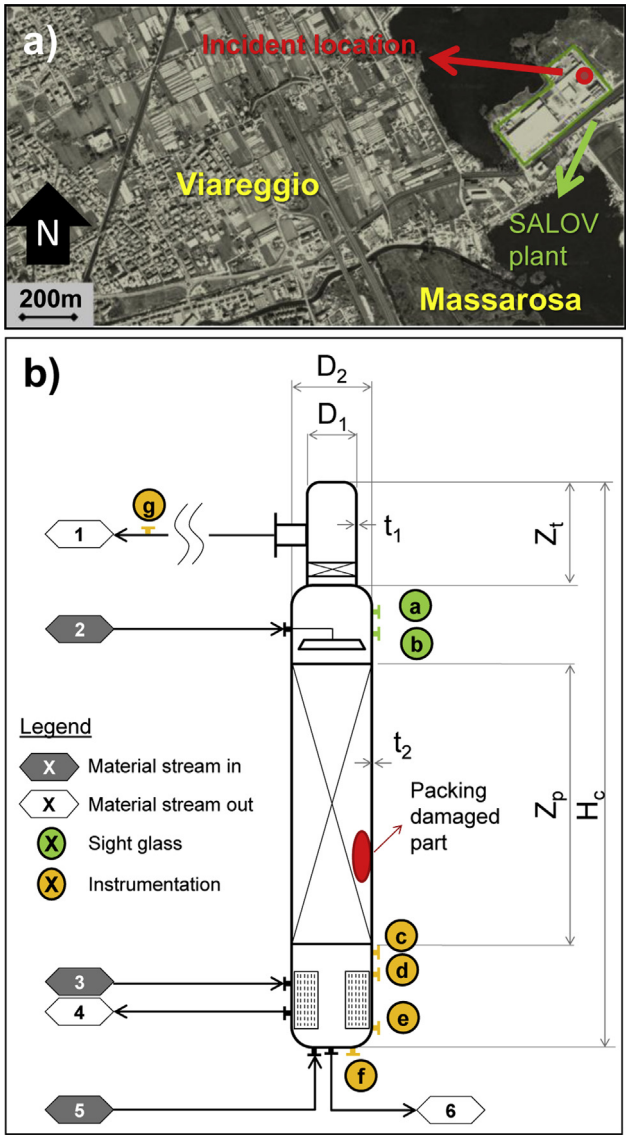

Fig. 1. a) Overview of the incident area, the plant and the damaged column location; b) process scheme and sketch of the damaged column. For items definitions and dimensions refer to Table 1.

At about 7:45 am (September 27th) the process operators noticed some black smoke issuing from the top of the column from the sight glass, and an inspection was carried out, evidencing structural damages on the outer surface of the column, shown in Fig. 2a (the picture was taken during the inspection). As reported in Table 1, the column was provided with a thermal insulation (rock wool) incapsulated in a thin watertight steel sheet coating, with no air gap left between the sheet and the coating. Together with the deformation damages, the outer steel sheet presented evidences of strong oxidation (see the three dark spots in Fig. 2a). Next, on October 2nd, the damaged steel sheet and the insulating coatings were removed; strong plastic deformation on the wall of the column itself was observed (see Fig. 2b). Finally, on November 2012, the column was dismounted and sectioned in several parts also showing the internal damages on the structured packing (Fig. 2c) and the evidences of solid residual accumulation.

Since the plant was unmanned during the incident, no harm was caused to workers, but this event was analyzed in order to provide safety improvement in this type of processes and maintenance operations.