Recycling paint sludge in asphalt pavements: cost-benefit and life cycle assessment

B. Ruffino[1], A. Farina[2], A. Vercelli[1], D. Dalmazzo[1], G. Blengini[1], M.C. Zanetti[1], E. Santagata[1]

[1]Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, Torino, I-10129, Italy
[2]College of Engineering, Michigan State University, East Lansing, Michigan, 48824, USA
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Presenting author email: barbara.ruffino@polito.it

Application of paints by spraying, extensively used in automotive industry, is a significant source of solid waste. Currently, the generation of paint sludge (PS) in Italian plants is in the order of 3 kg/car on a wet basis (data from FCA, 2016). This waste, when improperly managed, leads to serious environmental problems, because of its hazardousness and activity. Presently, most part of PS is incinerated in special combustion plants or cement kilns or disposed in landfills for hazardous or non-hazardous waste, depending on the hazardousness level of sludge.

Solutions alternative to incineration or landfilling have been considered since the early Nineties in order to reduce the impact of PS on the environment and recover valuable materials. For example, researchers from Ford company studied the technical feasibility of pyrolizing PS to an activated carbon-like adsorbent that can be useful to reduce emissions of VOCs from spray booths (Kim et al., 2001). Other works considered the recycling of inorganic pyrolysis residues, made of metal oxides, into the same source materials (paint fillers) from which they originated, and the collection and subsequent burning of pyro-oil and pyro-gas (Nakouzi et al., 1998). Towards the end of the Nineties, ASTER proposed a solution to recycle PS into ingredients for automotive sealants (Gerace et al., 2002). In 2007, Indian researchers developed a treatment made of phases of consecutive rinsing with several solvents, drying, milling and sieving for the conversion of PS into a reusable paint (Bathia et al., 2007). In all the afore-mentioned case-studies the waste products generated in car manufacturing processes was recycled into the same process.

Recently, the reuse of PS as a replacement/substitute of a part of the conventional binder for the production of concrete for asphalt pavements was proposed and the technical feasibility of the process was successfully demonstrated (Dalmazzo et al., 2017). However, for a more complete assessment of the aforementioned recovery process, the technical feasibility must be combined with the economic and environmental sustainability. As shown in Figure 1, unlike the traditional process of asphalt concrete production, the employment of PS requires two additional phases, named (1) sludge preparation through the operations of dewatering and milling and (2) mixing of sludge with bitumen.

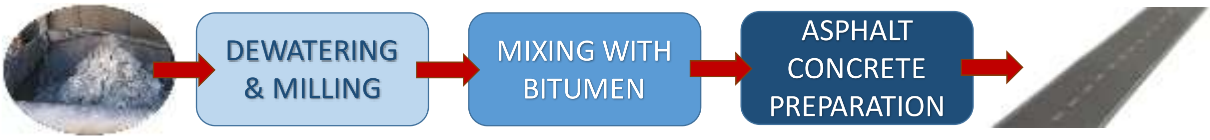

Figure 1. Scheme of the paint sludge recycling process

The economic assessment of the recovery process was carried out by making reference to a PS production rate of 3000 t/y. The annual operating cost items (i.e. installment, utilities, maintenance and labor) of the two phases were calculated in order to obtain an overall unit treatment cost. In full scale applications, dewatering and milling are jointly carried out in a thermal plant capable to reduce the original PS water content equal to approximately 60% (w/w, on a wet basis) to values of less than 15%. The evaporation of water needed a thermal power of 220 Mcal/h generated from the combustion of natural gas. The purchase costs of the main pieces of equipment that constitute the thermal plant and the operating costs for maintenance, labor, electricity and natural gas supply returned a unit cost of 95 €/t for the phase of sludge drying and pulverization.

Mixing of pulverized PS with neat bitumen required a mixer with an operating volume in the order of 5 m^3. One of the most relevant feature of the mixer is the presence of a jacket containing heated oil with the purpose of guaranteeing the temperature of 150°C during the mixing phase. The sum of the installment cost and the costs for electricity and natural gas supply (for oil heating) returned a unit cost of 104 €/t of dried sludge for the preparation of the binder from PS. This cost decreased to 49 €/t if it was referred to the sludge with the original moisture content (60% w/w, wet basis). Consequently, the unit cost of treatment, that includes the operations of phase 1 and 2, was of 144 €/t. The economic balance was positive, because, as demonstrated in the work of Dalmazzo and coauthors (2017), a PS treated at a cost of 144 €/t could substitute up to 20% of neat bitumen (at a cost of 450 €/t) in a binder used for asphalt concrete production without worsening the performances of the pavement.

For the assessment of the environmental sustainability of the PS recycling process, an LCA analysis "from cradle to gate" was carried out by using SimaPro software. The analysis considered the energy required for PS pulverization and the transportation of PS and neat bitumen to the site where the two ingredients are mixed to obtain the PS-modified binder, as shown in Figure 2. In addition, the LCA analysis included the transportation of mineral aggregates for the production of asphalt concrete and the electricity and fuel (natural gas) supply involved in this operation. The recovery process of PS allowed the producers to avoid the incineration in a dedicated plant, with consequent economic savings.

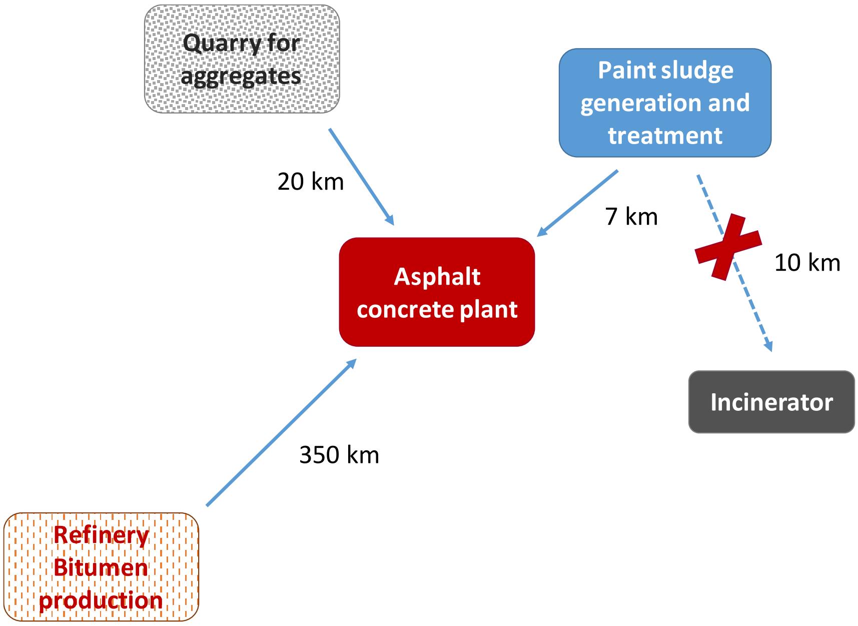

Figure 2. Scheme for the implementation of the LCA

The LCA analysis revealed that the production of a hot mix asphalt by employing a bitumen with the addition of 20% (w/w) PS, reduced the Gross Energy Requirement (GER) by approximately 16% respect to the traditional process. The Global Warming Potential (GWP) index decreased from 52.6 to 31.7 g CO_2eq/kg asphalt mixture.

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