Characterization of road sweeping waste in view of developing specific strategies to enhance its valorisation

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Abstract

The aim of this study was to characterize samples of road sweeping waste collected in a small/medium sized municipality of central Italy to identify a preliminary treatment train to allow the recovery of fractions with a valorization potential, and in particular inert materials such as sand and gravel. Two samples were collected during different seasons and characterized in terms of particle size distribution, material composition and chemical composition analysis. In addition, the leaching behavior as a function of particle size was also investigated. The different size fractions of both samples presented a quite low content and also leaching of regulated elements and anions. The most critical aspect was the relatively high Total Organic Carbon (TOC) content, between 2 and 5%, found for all fractions, in line with the very high Dissolved Organic Carbon (DOC) concentrations retrieved in the leachates, especially of the fine and coarsest fractions. On the basis of the results of the characterization analyses, a treatment for washing and separating the organic-rich fraction from the inert one was tested for several particle size classes. Results showed that the treatment proved effective in improving the leaching behavior of the resulting inert material-rich sink fraction in terms of the release of both trace elements and DOC. Based on the results obtained in this study for sample 2, by sieving and the tested washing/density separation treatment, a 50% recovery of the amount of input road sweeping waste, as sand (19%), fine gravel (27%) and coarse gravel (4%) was estimated.

Keywords: road sweeping waste, recovery, total content, leaching, washing treatment.

1. Introduction

The European Commission's commitment to enhance the transition towards a circular economy will greatly affect waste management policies and strategies in the next few years. In fact, the targets for 2030 reported in current revised legislative proposals are very ambitious both with regard to the reduction of Municipal Solid Waste (MSW) landfilling (<10% of residual MSW and banned for separately collected fractions) and material recycling (>65% of MSW) [1]. For many Countries, especially Southern and Eastern European ones, the achievement of these targets will be very challenging, considering that currently their waste management strategies still depend greatly on landfilling [2].

In Italy, the waste management strategies applied and recycling rates achieved vary greatly on a Regional basis. In order to promote material recycling and landfill avoidance, increasing targets for separate collection of MSW have been established in the last decade. The 2012 target of 65% of separate collection was nearly reached in 2016 (64.2%) in Northern Italy, while at a National level it was around 52.5%, due to the lower separate collection rates achieved in Central (48.6%) and Southern (37.6%) regions [3]. In 2016, the Ministry of the Environment issued a new guideline to calculate separate collection percentages, including recovered material from bulky waste, construction and demolition waste collected from households, as well as from road sweeping waste [4]. The Italian Environmental Protection agency (ISPRA) estimated that already in 2016 the inclusion of these fractions allowed to increase the separate collection value of 2 points, from 50.5 to 52.5% [3]. Considering that treatment facilities for the above mentioned types of MSW aimed at recovering recyclable materials are quite recent, it is evident that improving material recovery from these fractions may lead to a significant increase in terms of separate collection and recycling rates.

In the case of road sweeping waste, that is considered to amount to 3-5% of MSW production, for Italy a total production of 0.9-1.5 M tons can be estimated for the year 2016, considering an overall MSW production of 30.12 M tons [3]. Road sweeping (or cleaning) residues (identified by the European waste code 200303) are a very heterogeneous type of waste, mainly made up by dust, soil, stones, gravel, sand, leaves, paper, packaging materials, and others (e.g. cigarette butts, organic materials and other improperly disposed of waste). Their composition varies considerably depending on the season and other factors such as type of roads and neighbourhoods [5-6]. Main potential contaminants that may be retrieved in this type of waste, and that may be released to the environment when in contact with water, include metals, salts and organic compounds [5-6].

Up to recently road sweeping waste was almost exclusively disposed of in non hazardous waste landfills. However, in the last few years an increasing number of treatment plants have started operation with the aim of recovering materials from this MSW stream. The materials that can be recovered from road sweeping waste are mainly sand and gravel. Also the organic fraction, if it contains a low amount of organic and inorganic contaminants, could be treated by aerobic or anaerobic digestion to produce compost or digestate and energy, respectively. However, a study by the UK's EPA pointed out that the compost obtained by treating street leaf sweepings presented a similar content of metals compared to compost from source-collected green household waste, but higher levels of polycyclic aromatic hydrocarbons, concluding that street leaf sweepings should not be composted [7]., As for the packaging material that can be separated from the waste, washing treatments may be applied to allow to send them to recycling facilities along with the flows collected from at source separate collection of MSW. The treatment capacity of these types of plants is typically around 100 ton/d and they present a similar layout, characterized by several size separation steps, a washing treatment aimed at cleaning the recovered fractions, but also at separating the inert materials (gravel and sand) from the organic rich fractions, and finally a wastewater treatment plant. Recovery rates of inert materials are reported by the treatment facilities to range between 60 and 70% of the treated waste. In 2016 around 215,500 tons of materials obtained by the treatment of road sweeping waste were sent to recycling in Italy, 86% in Northern regions and only 10 and 4% in Central and Southern ones respectively [3]. As shown in Table 1, compared to other types of MSW fractions, the recovery of materials from road sweeping waste is currently much less applied and is hardly performed in Central regions (where there is only 1 plant in operation), while practically nonexistent in Southern Italy.

The aim of this work was to characterize samples of road sweeping waste collected from a small-medium sized municipality of Central Italy, to analyze their material and chemical composition, as well as leaching behavior as a function of particle size, with the final aim of identifying a simplified treatment layout that may be applied also for smaller sized plants (e.g. 10 ton/d capacity). This way the plants could be located in the proximity of towns in Central and Southern Italy, minimizing transport. On the basis of the results of the characterization analyses, a treatment for washing and separating the organic rich fraction from the inert one was tested for several particle size classes.

Tab.1 Percent of Italian Municipalities that separately collected specific waste fractions in 2016 [3]

Waste fraction	North (%)	Centre (%)	South (%)	Italy (%)
Organic fraction	95.1	89.6	78.6	89.2
Paper and cardboard	99.8	96.6	94.2	97.6
Glass	99.2	93.5	93.0	96.6
Plastics	99.5	93.0	92.4	96.5
Wood	87.0	65.5	36.1	68.3
Metals	96.0	84.1	77.0	88.5
WEEE	96.1	82.4	74.9	87.8
Textiles	74.2	75.8	69.1	72.8
Bulky materials	88.5	73.0	64.1	78.9
C&D from households	68.3	44.1	22.0	50.7
Recovered material from road sweeping waste	**40.9**	**8.1**	**2.7**	**24.9**

2. Materials and methods

2.1 Sampling and characterization

The two samples of road sweeping waste examined in this study were generated from a municipality of 60000 inhabitants located in central Italy, close to the coast. Specifically, the samples (weighing roughly 20 kg each) were collected directly from the container (see Figure 1) in which road sweeping vehicles void the waste they accumulate during their daily rounds. In both cases the samples were collected shortly after the waste was emptied into the container, therefore they should be representative of as-collected road sweeping waste. Sample 1 was collected in November 2017, while sample 2 was collected in January 2018. It should be noted that local climate conditions during the week preceding each sampling were quite similar (average temperature of 12 °C); however the week preceding the November sampling was more rainy (5 out of 7 days) compared to the one before the January sampling (2 out of 7 days).

The as received samples were dried under a laboratory hood at ambient temperature for about 1 week. Subsamples of the as received samples were employed to analyze the water content of the material by oven drying at 105 °C until constant weight. Characterization of the dried samples included particle size distribution, material composition and chemical composition analysis. In addition, the leaching behavior as a function of particle size was also investigated.

Fig. 1 Container from which the road sweeping waste samples were collected

Particle size distribution was determined by sieving, while material composition analysis was performed on specific particle size fractions (i.e. d>76.2 mm and 12.7≤d<25.4 mm for both samples and also 25.4≤d<49 mm for sample 2) by visual inspection separating and weighing the different types of materials making up the waste. Table 2 reports the types of chemical analysis performed on the different particle size fractions of the two samples and the limit values that were considered as reference to assess the reuse potential of each fraction. Guideline values for the recycling of this specific type of material, which may be considered as a mixture of soil and waste, have not been issued; hence, the chemical properties of the analyzed samples were compared to limit values for soil (total content) or waste (leaching) utilization.

Tab. 2 Types of analysis performed on the different particle size fractions of the two samples and limit values considered as reference for assessing their reuse potential

	Analyzed fractions		**Legislation and limit values considered as reference**
	1st sample (Nov. 2017)	2nd sample (Jan. 2018)	
	Total content analysis		
Main and trace element contents (EPA method 3050B) (mg/kg)	d < 0.7 mm 0.7 ≤ d < 1.19 mm 1.19 ≤d < 2 mm	d < 0.7 mm 0.7 ≤ d < 2 mm	It. Lgs. Decree 152/06 [8] Soil contamination threshold concentrations for residential areas
TOC (% wt.)	d < 0.7 mm 0.7 ≤ d < 1.19 mm 1.19 ≤ d < 2 mm 2 ≤ d < 4 mm 4 ≤ d <6 mm 6 ≤ d < 9.52 mm	d < 0.7 mm 0.7 ≤ d < 2 mm 2 ≤ d < 4 mm 4 ≤ d <6 mm 6 ≤ d < 9.52 mm	It. Min. Decree 27/9/2010 [9] Waste acceptance criteria for inert waste landfills
	Leaching behavior		
Eluate contents of main and trace elements and of chlorides and sulfates (EN 12457_2) [10] (mg/l)	d < 0.7 mm 0.7 ≤ d < 1.19 mm 1.19 ≤ d < 2 mm 2 ≤ d < 4 mm 4 ≤ d <6 mm 6 ≤ d < 9.52 mm	d < 0.7 mm 0.7 ≤ d < 2 mm 2 ≤ d < 4 mm 4 ≤ d <6 mm 6 ≤ d < 9.52 mm	It. Min. Decree 186/2006 [11] Limit values for reuse of non hazardous waste under specific conditions
DOC (mg/l)	d < 0.7 mm 0.7 ≤ d < 1.19 mm 1.19 ≤ d < 2 mm 2 ≤ d < 4 mm 4 ≤ d <6 mm 6 ≤ d < 9.52 mm	d < 0.7 mm 0.7 ≤ d < 2 mm 2 ≤ d < 4 mm 4 ≤ d <6 mm 6 ≤ d < 9.52 mm	It. Min. Decree 27/9/2010 [9] Waste acceptance criteria for inert waste landfills

Specifically, main and trace element contents were determined by acid digestion of sub-samples of the fractions with d < 2mm employing HNO_3, H_2O_2 and HCl (EPA method 3050B), followed by ICP-OES analysis (Agilent 710-ES instrument) of the resulting solutions. The obtained concentration values of elements of environmental concern were compared to the respective soil concentration threshold values for residential areas [8]. The Total Organic Carbon (TOC) content of the samples was determined with a TOC analyzer (Shimadzu, TOC-VCPH) equipped with a sampler for solid materials (Shimadzu, SSM-5000A), by the difference between the total carbon and inorganic carbon contents. In this case, since TOC is not included in soil contamination threshold parameters, as limit value the Italian acceptance criteria for inert waste landfills was considered [9], which correspond to the European Community's acceptance of waste at landfills [12].

As for the evaluation of the leaching behavior of the different fractions, the standardized batch compliance test EN 12457-2, which employs a liquid to solid ratio of 10 l/kg and a contact time of 24 h, was adopted [10]. The obtained eluates were analyzed by ICP-OES to determine main and trace element contents, by ion chromatography (Dionex ICS 1100), to assess chlorides and sulfates concentrations, and with the previously mentioned TOC analyzer to evaluate the Dissolved Organic Carbon (DOC) content. In this case the resulting concentrations were compared to the limit values established in Italy for reuse following a simplified authorization procedure of different types of non hazardous waste in specific applications [11], except for DOC for which the acceptance criteria for inert waste landfills was considered [8].

2.2 Washing/separation treatment

In order to improve the composition and leaching behavior of the sub-samples resulting from physical separation of the analyzed road sweeping waste, a treatment aimed at both washing and separating the material on the basis of its specific weight was tested. The treatment consisted in contacting 100 g of a specific size fraction (i.e. d < 0.7 mm, 0.7 ≤ d < 2 mm, 2 ≤ d < 4 mm, 4 ≤ d <6 mm and 6 ≤ d < 9.52 mm) of dried sample 2 (collected in January 2018) with 1 l of deionized water. The suspension was stirred for around 5 min and then left to settle for 1.5 h. The float fraction was then removed with a strainer, dried and weighed, while the sink fraction was recovered by vacuum filtration of the solution with 20-25 μm filters in cellulose acetate. Also these solids were dried at 105 °C and weighed.

The sink fractions, which were supposed to be enriched in inert material, were then analyzed to determine their TOC content and leaching behavior adopting the same methods reported in paragraph 2.1.

3. Results

3.1 Characterization

This paragraph reports the results of the characterization analysis performed for the two samples of road sweeping waste collected during different periods of the year from the municipality selected as case study. It should be noted that only two samples were examined as the aim of the study was to identify a preliminary treatment train that may allow the recovery of fractions with a valorization potential, not to evaluate the seasonal variability and heterogeneity of the waste.

The humidity contents of the two samples were quite comparable (17% for sample 1 and 15% for sample 2), showing not to be greatly affected by the weather conditions of the week preceding sample collection.

Figure 2 reports the particle size distribution of the analyzed samples. As can be observed, the two samples presented a very similar distribution for a particle size larger than 10 mm (around 20-23% of the sample's weight). Instead, sample 1 presented a higher content compared to sample 2 of the fraction between 2 and 10 mm (54 versus 35%), while a lower amount of the fraction below 2 mm (23 versus 45%). In terms of the recovery of inert materials to use in construction applications, the particle size fractions of interest are: 0.7 to 2 mm (sand), 2 to 8 mm (fine gravel) and 8 to 20 (coarse gravel). On the basis of particle size analysis, the average contents of the above mentioned fractions for the analyzed samples were: 0.7 to 2 mm=17%, 2 to 8 mm = 39% and 8 to 20 mm = 13.5%.

Hence, just considering particle size point of view, around 70% of the analyzed road sweeping waste would present suitable characteristics for recovery as a construction material. However, as previously mentioned, this type of waste is very heterogeneous in composition and contains also other types of materials. The main material content of some of the coarse fractions (d>12 mm) was hence evaluated by material composition analysis, while the amount of recoverable inert material from the finer fractions of sample 2 was instead inferred on the basis of the results of the washing/separation treatment reported in paragraph 3.2.

As can be observed in Figure 3 and Table 1, the composition of the coarsest fraction (d>76.2 mm) found for the two samples was quite comparable, with a predominance of organic material, i.e. leaves, pine needles and cones, (around 75%), followed by paper and cardboard (16%) and other materials, such as aluminum cans, plastics, textiles or wood, depending on the sample. A much higher variability in composition was found for the particle size fraction between 12.7 and 25.4 mm. The sample 1 fraction presented a prevalence of inert materials

(70%), followed by leaves and pine needles (25%), some glass fragments and paper and cardboard. The sample 2 fraction was instead predominantly made up by organic material (90%), with only 2.6% of inert fractions, the rest being glass fragments, paper and cardboard and cigarette butts. The results found for the 25.4≤d<49 mm fraction of sample 2 (not shown in Figure 3 and Table 2) were quite in line with those found for the other two fractions examined for this sample, with an intermediate content of organic material (80%) and paper and cardboard (8%) with respect to the other two, and a slightly higher amount of inert materials (6%).

The results of the material composition analysis, as well as visual inspection of the different particle size fractions, indicated that materials other than gravel, leaves/pine needles or cones, were predominantly found in the coarsest size fraction. For sample 2 in all the fractions with d> 12.7 mm organic rich materials predominated, while instead for sample 1 a significant amount of inert fraction could be retrieved in the 12.7-25.4 mm fraction.

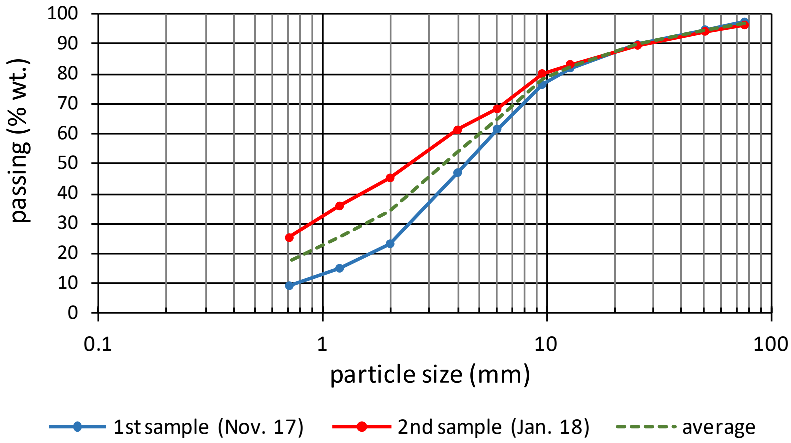

Fig. 2 Particle size distribution of the two analyzed samples of road sweeping waste

Fig. 3 Material composition analysis of: (a) d>76.2 mm (sample 1); (b) 12.7<d<25.4 mm (sample 1); (c) d>76.2 mm (sample 2); (d) 12.7<d<25.4 mm (sample 2).

The fractions presenting a particle size below 2 mm were analyzed to determine their content of major elements and components of environmental concern. As can be noted in Fig. 4a and 4b, the elemental content of sample 1 was quite similar for the three size fractions considered, however the finest one (d<0.7 mm) was generally characterized by a higher content of most elements (e.g. Al, Ca, Be, Cr, Cu, Mo, Ni and Pb), in agreement to what reported in previous studies carried out on this type of waste [13]. Also the finer fraction of sample 2, for which only two fractions were analyzed on the basis of what was found for the first sample, showed to be enriched in Cr, Cu, Mo, Ni and Pb; however, the same trend was not found for Al, Ca and Mg, which showed a higher content in the coarser fraction (0.7≤d<2 mm). Overall, the concentration of both major and trace elements in the two samples were quite comparable, although sample 1 exhibited a higher content of Fe and of most elements of environmental concern, such as Cu, Pb and Zn. Comparing these results with the limit values considered as reference for assessing their reuse potential, it can be observed that for sample 1 all three analyzed fractions showed exceeding values for Cr in particular, but also Zn and Be, while for sample 2 only Cr appeared to be critical for both size fractions, since Zn reached the limit value only for the fine fraction.

Tab. 3 Material composition analysis results

	d> 76.2 mm		12.7<d<25.4 mm	
	1st sample (%)	2nd sample (%)	1st sample (%)	2nd sample (%)
organic fraction	73.4	78.2	24.9	90.5
plastics	1.7	1.6	0.5	0.2
paper and cardboard	17.5	14.0	1.4	3.5
metals	0.0	6.2	0.2	0.0
textiles	3.9	0.0	0.0	0.0
wood	3.5	0.0	0.0	0.0
glass	0.0	0.0	3.1	2.4
inert material	0.0	0.0	69.9	2.6
others (cigarette butts)	0.0	0.0	0.0	0.7

As illustrated in Figure 5a, the TOC content of the different particle size fractions of the two samples varied between 1.5 and 5.2 % by wt. and did not exhibit a clear trend as a function of grain size, although the concentrations found for sample 2 were slightly higher and, except for the 4-6 mm fraction, showed to increase with particle size. The average concentration resulting for all of the analyzed samples appeared to be just above the reference value considered (3% for inert waste landfilling).

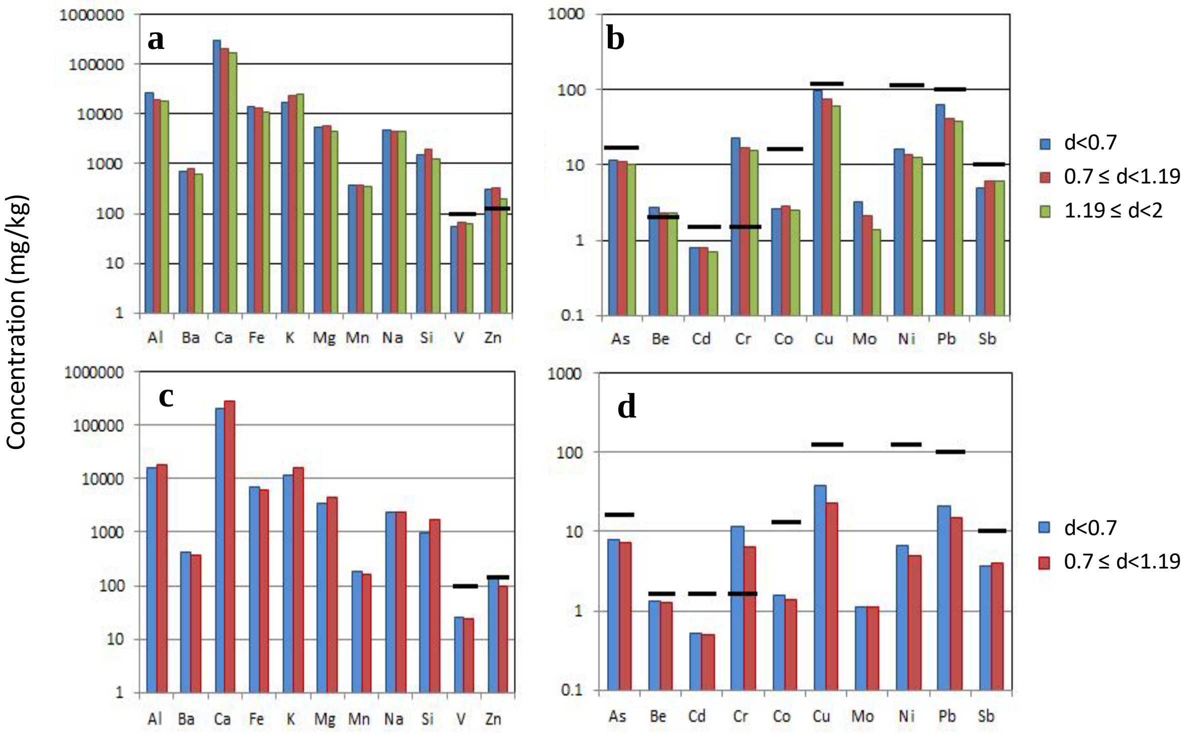

Fig. 4 Concentration of major and trace components of environmental concern in different particle size fractions of sample 1 (a and b) and sample 2 (c and d). The black lines refer to the limit values considered as reference.

As for the leaching behavior of the two samples, as can be observed in Figure 6, for most metals only a small fraction of the total content (reported in Figure 4) was released, many elements presenting an eluate concentration below instrumental quantification limits. The results also indicate that although the overall leaching concentrations of both major and trace elements were of the same order of magnitude for the two samples (apart from Al and Fe that were higher for sample 1), their trend with particle size was opposite. In fact, while for sample 1 the finest fraction (d<0.7 mm) exhibited a higher release of most elements (e.g. Ba, Zn, Cu, Fe and Ni), for sample 2 the coarsest one (6≤d<9.52 mm) presented a higher eluate concentration of both major and trace constituents (e.g. Al, Fe, Zn, Cu and Sb). With regard to the comparison with the limit values considered as a reference for reuse, for the finest fraction of sample 1, Ba, Cu and Ni release appeared to be critical, whereas for sample 2, only Cu leaching from the coarsest fraction analyzed proved higher than the respective limit. The pH of the eluates ranged between 7.1 and 7.3 for sample 1, and 6.9 and 7.5 for sample 2, exhibiting no particular trend with particle size.

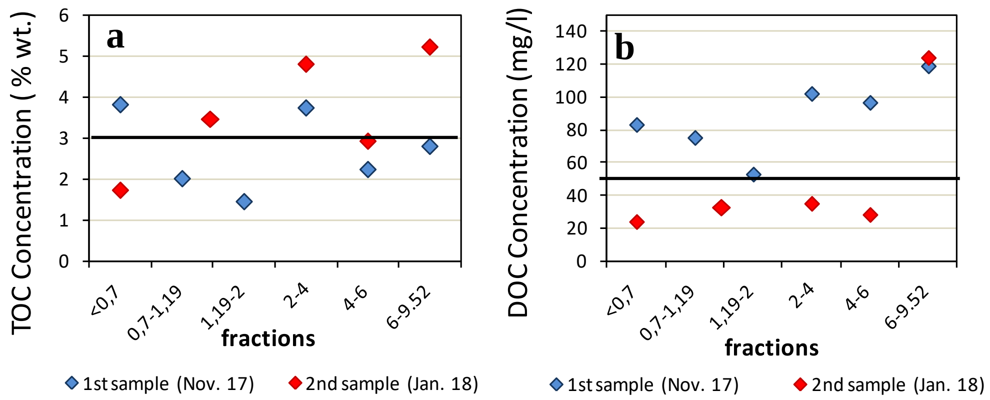

Fig. 5 (a) TOC content and (b) DOC concentration of different particle size fractions of the two samples of road sweeping waste. The black lines refer to the limit values considered as reference.

The DOC release from the different size fractions of the two samples, reported in Figure 5b, showed to vary between 20 and 120 mg/l, corresponding to 1-2% of the TOC content of the samples. In this case, a higher eluate concentration was obtained for the fractions of sample 1 compared to those of sample 2, except for the coarsest fraction analyzed, which in both cases presented the highest DOC release. All the analyzed fractions appeared to be critical in terms of DOC leaching for sample 1, while only the 6≤d<9.52 mm fraction exceeded the 50 mg/l limit for inert waste landfilling.

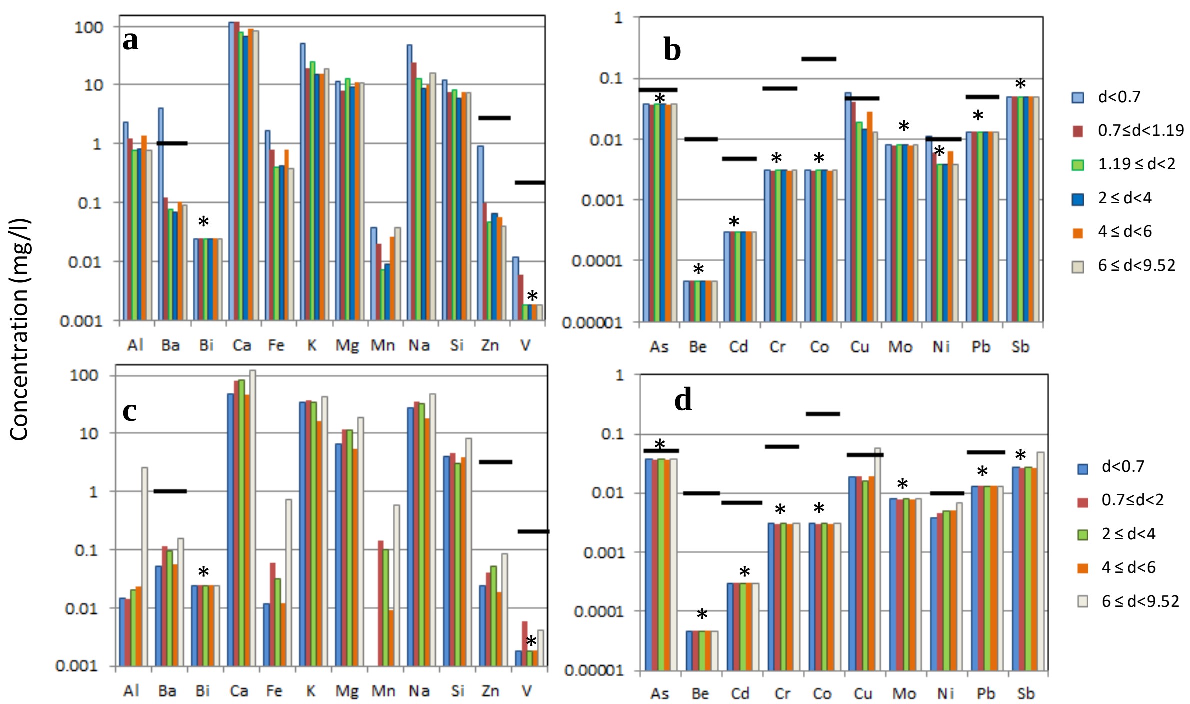

Fig. 6 Concentrations of major and trace components of environmental concern in the eluates resulting from different particle size fractions of sample 1 (a and b) and sample 2 (c and d). The black lines refer to the limit values considered as reference, while stars indicate concentrations lower than the instrument quantification limit (the reported concentrations correspond to the quantification limit)

Finally, in terms of anions release, chloride leaching ranged between 10 and 25 mg/l for sample 1 and 25 and 70 mg/l for sample 2; sulfate release was comprised between 2.5 and 6 mg/l for all size classes of sample 1, except for the finest one (14.6 mg/l), and between 3 and 11 mg/l for all fractions of sample 2, except for the coarsest one (13.6 mg/l). The higher Cl release from sample 2 may be tentatively ascribed to the fact that during the week preceding the collection of that sample there had been less rainfall which may have caused a lower washout of the most soluble components. This hypothesis is supported by the higher K and Na contents retrieved in the fractions of sample 2 compared to sample 1. Anyhow, in all cases the measured concentrations of chlorides and sulfates proved lower than the limit values considered for reuse (100 and 250 mg/l, respectively).

3.2 Washing/separation treatment

The results of the characterization analysis indicated the prevalence of organic materials in most of the coarse fractions (d>12 mm) of the two analyzed samples, but also a significant content of organic carbon in the finer fractions that present the highest content of inert materials that may be potentially reused. A washing/separation treatment was tested at lab scale (see Figure 7a) to reduce the TOC content of the inert materials, the release of DOC and of other trace constituents.

As shown in Fig. 7b, the sink fractions resulting from the treatment prevailed in weight (87-95%) with respect to the float ones (1.6 to 11%). It should be noted that in each test a weight loss of 2-3% was obtained due to difficulties in recovering all of the separated material.

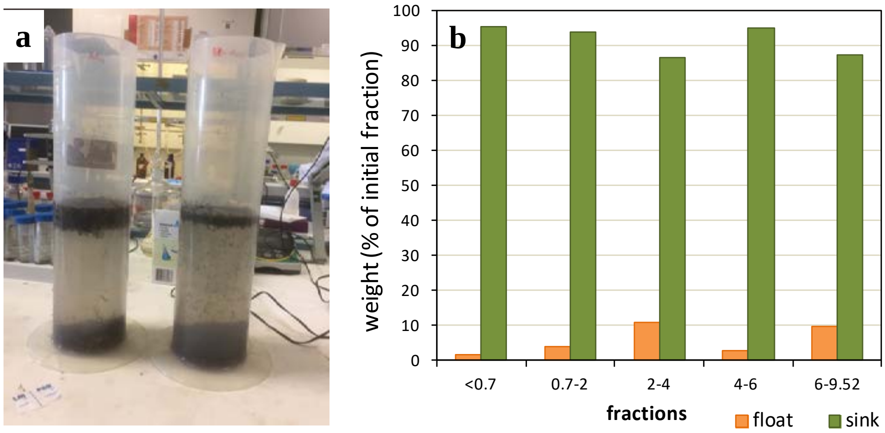

Fig. 7 (a) Lab-scale washing/separation treatment; (b) Weight of the sink and float fractions with respect to the initial weight of the sample for the different particle size fractions.

As shown in Figure 8a, except for the fraction with 2≤d<4 mm the sink material did not exhibit a noteworthy reduction in TOC content after the treatment. In this graph standard deviations are also reported in order to show the variability of the results, which indicate that, apart from the fraction mentioned above, for all the others the TOC concentration was not affected by the treatment. However, Figure 8b shows that the DOC concentration of the eluates of the sink fractions decreased significantly for all the grain size fractions, and in particular for the coarser one (5 fold decrease), resulting well below the limit for inert waste landfilling. The DOC analysis of the leachate of the float fractions ranged between 103 and 518 mg/l, more than an order of magnitude higher than the corresponding values retrieved for the sink fraction. These results suggest that the density separation treatment was effective in obtaining a sink fraction characterized by a less mobile organic carbon content compared to the feed waste. .

As for the effects of the treatment on the leaching of major and trace elements, Figure 9 reports the release of these constituents from the sink fraction obtained by treating the different fractions of sample 2. Comparing these results with those reported in Figures 6c and 6d, it is evident that the washing treatment reduced the leaching of all elements (with the exception of Fe) and also its variability with particle size. Hence, the washing treatment showed to be particularly effective for reducing the leaching of trace elements of environmental concern from the coarsest particle size fraction. The pH of the eluates of the sink fractions were slightly higher compared to those of the untreated fractions and ranged from 7 to 8.2. As for the effects of the treatment on chloride and sulfate leaching, as expected the concentrations in the eluate of the sink fractions, around 10 and 2 mg/l, respectively, were considerably lower than those resulting for the untreated sub-samples.

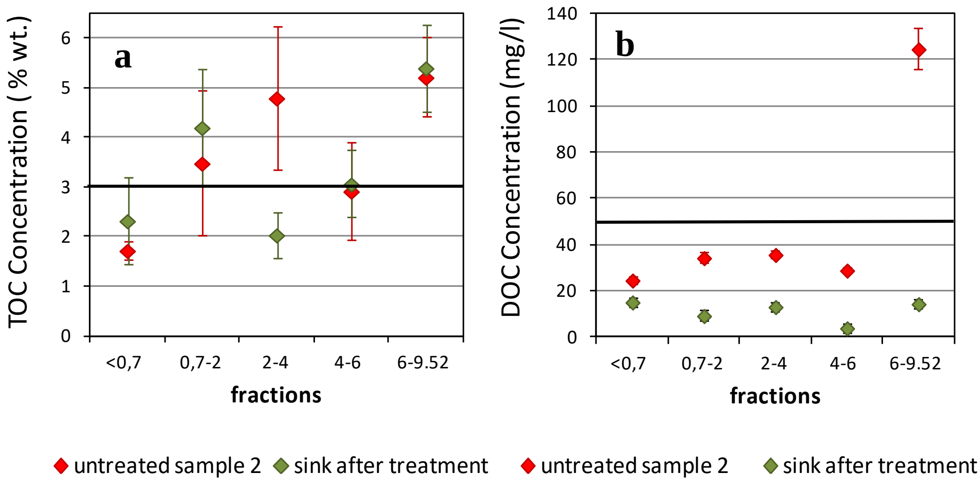

Fig. 8 (a) TOC content and (b) DOC concentration of the eluates of the sink fractions obtained after the treatment of different particle size fractions of sample 2 compared to that of the respective untreated ones. The black lines refer to the limit values considered as reference.

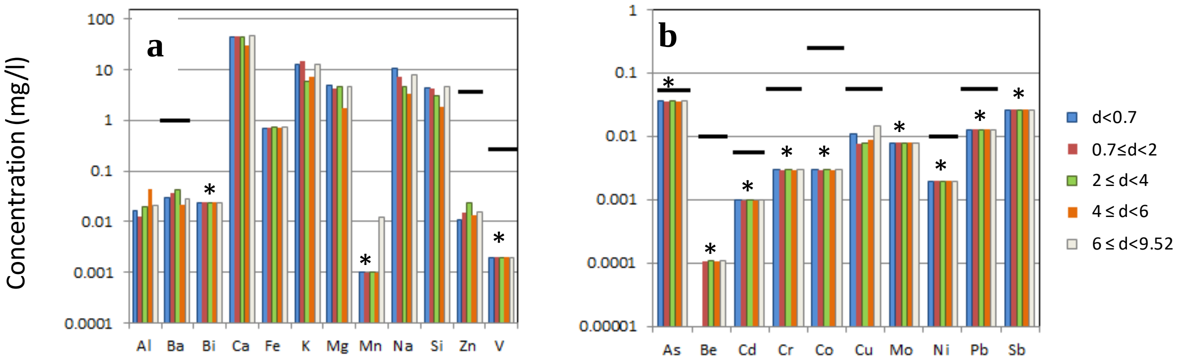

Fig. 9 Concentrations of major (a) and trace components of environmental concern (b) in the eluates of the sink fractions resulting from different particle size classes of sample 2. The black lines refer to the limit values considered as reference, while stars indicate concentrations lower than the instrument quantification limit (the reported concentrations correspond to the quantification limit)

4. Conclusions

This paper reports the results of an experimental study aimed at characterizing samples of road sweeping waste generated from a small/medium sized municipality located in central Italy with the aim of identifying a preliminary treatment that may allow the recovery of fractions with a valorization potential. Results indicated that just size separation would not be sufficient to obtain fractions that may be suitable for reuse in construction applications due to the high content of organic material retrieved in all of the analyzed particle size classes. The total content and especially release of elements of environmental concern resulted quite low, with only Zn and Cr presenting total contents higher than the considered reference limits, and Cu and Ba exhibiting eluate concentrations above reuse guidelines. The critical parameters for the recovery of specific fractions from both of the analyzed samples were hence TOC content and DOC release.

The tested lab-scale combined washing and density separation treatment proved effective in improving the leaching behavior of the resulting inert material-rich sink fraction in terms of the release of both trace elements and DOC. The TOC content of the sink fractions however showed to be quite similar to that of the untreated waste fractions. Further analysis should be carried out to characterize the organic compounds contributing to the TOC content of the different fractions before and after treatment, also in view of identifying suitable strategies for managing the separated organic material.

On the basis of the results obtained in this study for sample 2, by sieving the material and applying the tested washing/density separation treatment, a 50% recovery of the amount of input road sweeping waste, as sand (19%), fine gravel (27%) and coarse gravel (4%) can be estimated. As for other recoverable fractions, the most significant appears to be paper and cardboard for which a recovery of 1.2% of the input waste may be estimated. Obviously, as shown by this study, recovery rates may vary considerably due to the great heterogeneity of this type of waste material, hence the obtained results may be employed just as a preliminary indication on the recovery potential of the proposed treatment train for small scale road sweeping waste valorization plants.

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