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Treatment of stormwater sediments: Efficiency of an attrition scrubber – laboratory and pilot-scale studies

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ABSTRACT

The purpose of this research is to present the efficiency of an attrition scrubber in the decontamination of stormwater sediments. Application of the attrition process serves to remove fine particles and contaminants from the surface of materials, i.e. sediment in the present case. This mechanical method has been evaluated both on the laboratory scale and at a pilot plant; the two treatments display different operating parameters. This article will introduce a ratio, defined as (R = mass% of pollutant/total mass%), to quantify the effect of attrition on the removal of pollutants (organic matter and trace elements). Screening and attrition have made it possible to concentrate pollutants into the fine fractions at ratio R, extending from 1.9 to 6.6. These results show that an attrition scrubber can remediate contaminated sediment and moreover that the remediation of stormwater sediment is indeed possible.

1. Introduction

The expansion of road networks over recent decades and the resulting permeability loss have focused environmental priority on runoff control and management. As a consequence, stormwater runoff has been identified as one of the major causes of degradation of receiving waters [1–4]; hence, the construction of retention and infiltration ponds has been on the rise. By absorbing peak flows and allowing suspended materials to settle, these units exert an impact on both the flow and quality of effluent; yet if they are to remain effective or be placed back into operation, the accumulated sediments will have to be removed.

These sediments however are often polluted with heavy metals and hydrocarbons [5–8] and may present a risk for both the environment and human health.

The actual volume of contaminated sediment within the French territory is open to considerable debate [9]. Although surveys conducted offer widely varying results for quantities deposited or removed during cleaning operations, the tonnages are quite high (reaching some 5 million tons, [10]). Given these tonnage readings, the removal and disposal of residue constitutes a key issue for local authorities. It is therefore necessary to propose appropriate treatment techniques that satisfy environmental as well as economic criteria.

Physical treatment may be used for the remediation of contaminated sediments. Physical processes are typically designed to separate a clean coarse sediment fraction, since most contaminants are concentrated within the fine fraction. It is generally admitted [5,11,12] that polluted particles are concentrated in the fine fractions of sediments; in recent studies on pond sediment however, [13,14] demonstrated that metal distribution within the sediment displays no specific heavy metal enrichment from one fraction category to the next. Consequently, simple sieving aimed at separating a polluted fine fraction from a non-polluted coarse fraction would prove unsuitable; it was then proposed to apply the attrition technique to clean the sediments. Attrition scrubbing provides for excellent mixing and surface abrasion and has been used successfully, one example being to speed up the leaching dynamics of gold ores [15]. The attrition scrubber has also been employed as a suitable remediation process for contaminated soils; in this case, the process removes particles and contaminants from the surface of primary materials, i.e. soils [16–18].

The objectives of this study are twofold: (1) to determine the efficiency of a physical laboratory test, more specially attrition, in the decontamination of stormwater sediments; and (2) to confirm the results derived on a pilot unit.

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Table 1
Location and characteristics of the studied sediments

	Type	Location in France	Size (m^2)	Traffic (vehicles/day)
Chevirė	Infiltration	SW of Nantes	780	80,000
AhAh	Retention	Crosne (Paris)	593	–
B5	Infiltration	A 47 (Lyon)	420	72,200
B6	Infiltration	A 47 (Lyon)	620	72,200
B10	Retention/infiltration	RN 88 (St. Etienne)	660	85,600
B12	Retention/infiltration	RN 88 (St. Etienne)	1156	85,600

2. Materials and methods

2.1. Study sites

A bulk characterization, including organic matter and trace metal concentrations, was performed in order to select the sediments. Six pond sediments, collected in the French regions around Nantes, Paris, Lyon and Saint Etienne, were studied. In each case, three surface samples were extracted by means of a stainless steel hand shovel, with sample thickness varying between 5 cm and 10 cm. Samples were stored at a temperature of 4 °C prior to analysis. Table 1 presents these selected sites.

2.2. Analysis

Once the samples had been air dried, gently disaggregated and passed through a 2000-μm nylon sieve, analyses could be carried out on the <2 mm particle size fraction. Organic matter (OM) content was determined from the weight loss at 550 °C, in assuming no significant weight loss due to other soil phases below this temperature.

Analytical grade reagents (Merck Suprapur or Pro Analysis) were used for the chemical analyses, and all glassware was cleaned with 10% HNO_3 and then rinsed with deionized water. After heating the samples to 550 °C and dissolving the residue in a mixture of concentrated $HClO_4$ and HF, metal quantification was carried out either by inductively coupled plasma-atomic emission spectrometry (ICP-AES; Varian Liberty 220 model) or by flame or electrothermal atomic absorption spectrometry (AAS; Varian AA 300 and GTA 96, or PerkinElmer 5000 and HGA 500), depending on both the metal and the concentrations. An internal quality control solution was incorporated into each series: when deviation exceeded 5% for ICP-AES or 10% for AAS, the series was run again. In addition, two blank tests were included in each series, and a reference sediment certified by the Community Bureau of Reference (CRM 320, a river sediment) was analyzed using identical procedures. The quality of the analyses was verified using the reference sediment analysis and ensuring that results were within 2 standard deviations of the certified values [19].

Scanning electron microscopy (SEM) analyses were performed in a Hitachi S-570 with an Energy Dispersive Spectrometer (EDS) Tracor. SEM focuses an electron beam of several micrometers at 15 keV on the samples and then captures secondary electrons and X-ray emissions. The samples were dried and then coated with a palladium/gold (Pd/Au) deposit prior to SEM observations.

2.3. Treatment conditions

The experimental protocol described in Fig. 1 was applied for the laboratory and pilot tests. During the first step of the physical treatment, bulk sediments were sieved at two cutoff thresholds (S1 and S2) in order to obtain three (organic matter and trace element concentration) fractions, characterized as follows: coarse fraction (C) >S1, intermediate fraction (I) >S2 and <S1, and fine fraction (F) <S2. In the second step, the intermediate fraction (I) was submitted to an attrition test and a cutoff at S2 μm. The mass rate as a percentage as well as the organic matter and metal contents were evaluated. Attrition tests (see Fig. 2) were conducted to determine whether contaminants could be removed from the surfaces of sediment particles through scrubbing action.

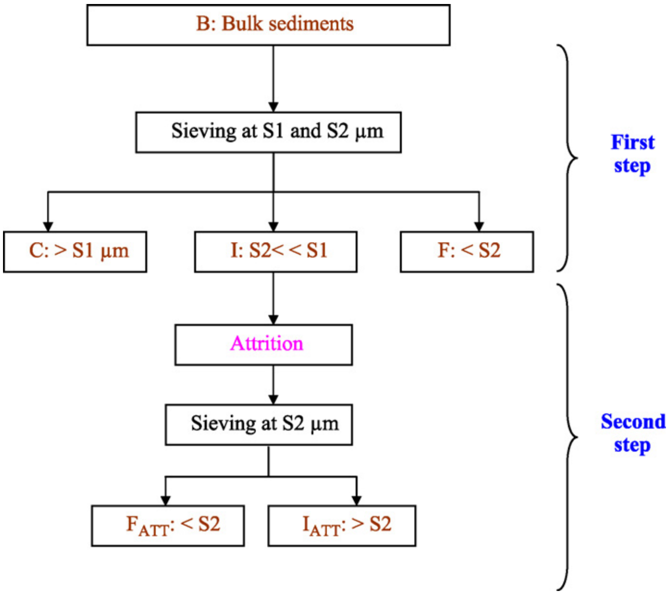

Fig. 1. Protocol for the treatment of stormwater sediments.

Attrition scrubbing performance and, therefore, the percentage of fine particles produced are generally studied by varying a number of parameters, including cutoff threshold, residence time, solid density and impeller speed.

Although many questions and relationships between variables remain unsolved, several series of attrition tests have been carried out: while [20] presented a typical testing matrix to determine optimal conditions, [21] and [16] developed different attrition series to investigate the effects of residence time on removal efficiency. A direct link between attrition duration and removal efficiency was observed by [16], whereas [21] found that extending the attrition scrubbing period, in order to remove further contaminant coating, only had limited effect. The attrition efficiency at different solid ratios was investigated by [17,22]; the best results were obtained after 65% and 75% of dry matter, respectively. Feng et al. [17] concluded that effective scrubbing (production of fine particles) decreases beyond an 80% solid ratio.

In this study, only the results obtained under optimal conditions [19] will be presented. The parameters used for laboratory and pilot testing are indicated in Table 2. The attrition test laboratory apparatus consists of three bladed impellers and a tightly fitted stainless steel tank with a lid. The impellers were built in one piece with all blades facing at opposite pitches and attached to the end of the shaft. The pilot machine was similar, but contained two cells each with a vertical tree and three levels of stirring paddles supplied by a 3-kW electric engine.

2.4. Presentation of results

In order to characterize treatment efficiency, results have been expressed in terms of the ratio defined as (R = mass% of pollutant/total mass%). When $R > 1$, the fraction describing a particular pollutant is enriched; otherwise, when $R < 1$, the fraction is depleted of one pollutant.

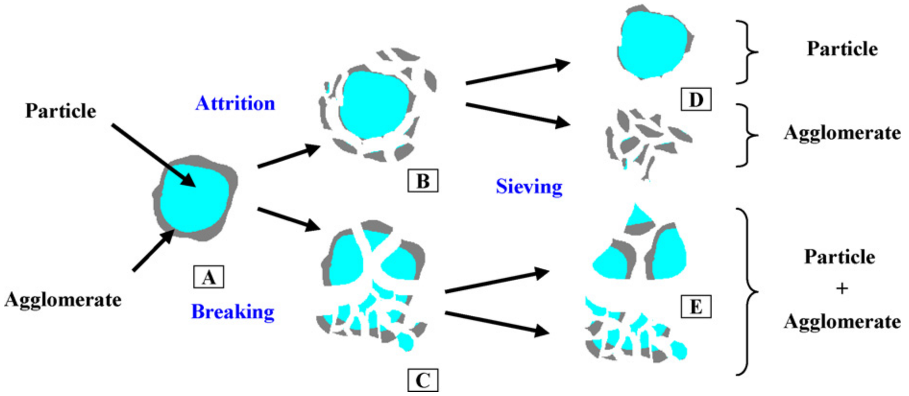

Fig. 2. Principle of attrition and comparison with the breaking process. A: initial coated particle, B: attrition, C: breaking, D: after attrition the particle is clean (blue on the figure), separated from the agglomerate (grey), E: after breaking the agglomerate remains clogged on the particle, there is no separation. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

3. Results and discussion

3.1. Characterization of bulk sediments

Organic matter percentages and trace metal concentrations in the various sediments are presented in Table 3 and compared with the target and intervention values from the Dutch standards for polluted soils [23]. Although these threshold values have no legal significance in France, they are frequently cited as references when interpreting the presence of certain substances in soils.

As can be seen from this table, most sediments display high concentrations. Organic matter percentages are greater than those required for reuse in road construction (10%) in Cheviré, AhAh, B5 and B6, with respectively 11.9%, 13.5%, 11.8% and 14.2%, and exceed levels in the B10 and B12 sediments (8.5% and 7.6%, respectively). The Cheviré and AhAh ponds are heavily contaminated with trace elements, especially with copper (281 mg kg^{-1} and 247 mg kg^{-1}) and zinc (1526 mg kg^{-1} and 1949 mg kg^{-1}), whose concentrations are higher than the Dutch standard intervention values. AhAh sediments are also contaminated with lead (357 mg kg^{-1}) and chromium (226 mg kg^{-1}). Copper concentration of the B10 sediments (199 mg kg^{-1}) also surpasses the intervention values. The other sediments are less contaminated, yet their metal concentrations still frequently lie above the target values, with for example 161 mg kg^{-1} of copper in B12, 109 mg kg^{-1} of chromium in B5 and 629 mg kg^{-1} of zinc in B6.

Table 2
Comparison between laboratory and pilot treatment conditions

	Laboratory conditions	Pilot conditions
Type of feed	Batch	Continuous
Cells (number)	1	2
Cutoff thresholds (μm)		
S1	2,000	2,000
S2	80	60
Length of treatment (min)	3	50
Impeller speed (rpm)	2,125	402
Solid density (% of dry matter)	74	70

3.2. Laboratory study

3.2.1. Distribution of pollutants vs. particle size

The ratios of OM and trace metals in the three fractions from the first step (Fig. 1), i.e. >2000 μm (C), 80–2000 μm (I) and <80 μm (F), were studied for six sediments to determine the distribution of pollutants with respect to particle size. Results are presented in Table 4. An example of calculation is given here for Cd in the B12 sediment. Cd percentage in the <80 μm of this sediment is 75, the total percentage of the <80 μm is 35, hence $R = 75/35 = 2.1$.

The coarse fractions, >2000 μm, are depleted with organic matter and trace element ratios of less than 1. These ratio values range from 0.2 to 0.8, which indicates a depletion of organic and inorganic pollutants. Furthermore, the ratio may vary in the coarsest fraction between the different sediments; for example, copper and nickel ratios lie between 0.2 and 0.5 of AhAh sediments, whereas the range stands at 0.6–0.7 for this fraction in Cheviré sediments.

In contrast, the finest grain size fraction (<80 μm) offered the highest ratio values. Despite variation from 1.1 to 2.3 depending on the actual pollutant and sediment, these values nevertheless indicate an enrichment of the fraction with regard to a particular pollutant.

For the intermediate fraction (I), the ratios are slightly lower than 1 and vary between 0.7 and 1.0, depending on the sediment under study. Even though the 80 μm to 2 mm fraction range is less contaminated, it still displays similar concentrations to bulk sediments. Attrition tests were performed in an attempt

Table 3
Characterization of the studied sediments, and comparison with the target and intervention values from the Dutch standard for polluted soils

	OM (%)	Cd (mg kg^{-1})	Cr (mg kg^{-1})	Cu (mg kg^{-1})	Ni (mg kg^{-1})	Pb (mg kg^{-1})	Zn (mg kg^{-1})
Cheviré	11.9	1.1	74	281	31	305	1526
AhAh	13.5	2.6	226	247	107	357	1949
RN88 – B10	8.5	0.6	81	199	38	156	585
RN88 – B12	7.6	0.6	92	161	44	102	411
A47 – B5	11.8	1.0	109	162	43	202	513
A47 – B6	14.2	0.9	83	168	44	182	629
Dutch target value	–	0.8	100	36	35	85	140
Dutch intervention value	–	12	380	190	210	530	720

OM: organic matter.

Table 4
Ratios (R = mass% of pollutant/total mass%) in the three fractions for the studied sediments

	OM	Cd	Cr	Cu	Ni	Pb	Zn
Cheviré							
>2000 µm	0.6	0.6	0.7	0.6	0.7	0.6	0.7
80–2000 µm	0.9	0.9	0.8	0.8	0.8	0.9	0.8
<80 µm	1.5	1.4	1.6	1.6	1.6	1.4	1.6
AhAh							
>2000 µm	0.4	0.2	0.4	0.2	0.5	0.3	0.3
80–2000 µm	0.9	0.9	0.9	1.0	1.0	0.9	1.0
<80 µm	1.7	1.6	1.6	1.6	1.2	1.6	1.6
RN88 – B10							
>2000 µm	0.6	0.6	0.7	0.2	0.7	0.2	0.2
80–2000 µm	0.9	0.9	0.8	0.8	0.7	1.0	0.7
<80 µm	1.2	1.3	1.4	1.5	1.5	1.4	1.7
RN88 – B12							
>2000 µm	0.3	0.2	0.3	0.4	0.7	0.1	0.2
80–2000 µm	0.9	0.8	1.0	0.7	1.0	0.8	0.7
<80 µm	1.8	2.1	1.6	2.0	1.4	2.1	2.3
A47 – B5							
>2000 µm	0.8	0.5	0.6	0.2	0.6	0.4	0.4
80–2000 µm	0.9	0.9	0.8	0.9	0.8	1.0	0.9
<80 µm	1.2	1.2	1.3	1.3	1.2	1.1	1.2
A47 – B6							
>2000 µm	0.6	0.8	0.5	0.1	0.8	0.3	0.4
80–2000 µm	1.0	0.7	0.7	0.7	0.8	0.7	0.7
<80 µm	1.1	1.2	1.2	1.2	1.2	1.2	1.2

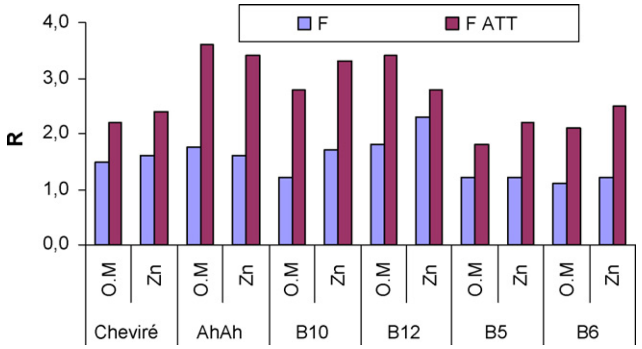

Fig. 4. Ratios (R = mass% of zinc/total mass%) for organic matter and mean trace elements of both the F (fine fraction after sieving) and F_{ATT} (fine fraction after attrition and sieving) fractions for the studied sediments.

to remove fine particles and pollutants from the intermediate fraction.

In spite of differences between the studied sediments and various pollutants, the ratio can be classified, after two sieving steps at 2 mm and at 80 µm, in the following order: $R_C < R_I \leq R_B = 1 < R_F$.

Fig. 3 allows to compare the Zn mass in the bulk (B), coarse (C), intermediate (I) and fine (F) fractions. As can be seen from this figure the Zn mass balance is quite good with the sum of Zn (C) + Zn (I) + Zn (F) ≅ Zn (B).

3.2.2. Fine particles resulting from the attrition process

The percentages of fine particles (F_{ATT}) produced as a result of attrition testing of the intermediate fraction (I) were determined by sieving at 80 µm. The values derived are presented in Table 5; these percentages may vary from one to three times depending on the sediment, with 12% for B10 vs. 31% for Cheviré. This fraction (F_{ATT}) corresponded to the aggregated fine particles, which are not easy to separate by sieving and necessitate the attrition step to be isolated.

The <80 µm fraction (F_{ATT}) ratio is calculated for each pollutant (OM and trace elements) in order to determine the degree of pollution and efficiency of the attrition step. The Zn and organic matter ratios for the fine particles resulting from attrition (F_{ATT}) are shown in Fig. 4 and compared to the same ratio for the fines (F) generated from sieving bulk sediments (i.e. the first step).

According to the sediments studied herein, organic matter ratios varied from 1.8 for B5 sediments to 3.6 for AhAh, whereas the Zn ratio ranged from 2.1 for B6 to 3.5 for AhAh. The <80 µm fractions resulting from attrition (F_{ATT}) were thus enriched in both organic and inorganic pollutants. Furthermore, the comparison between ratios for the F and F_{ATT} fractions indicates that F_{ATT} are more heavily concentrated than F, with a ratio 1.4–2.3 times higher.

The fine particles (fraction F), which remain free and easily separable by sieving, are shown to be less polluted than the other fine particles (F_{ATT} fraction), which are aggregated around coarse particles and separable after an attrition step.

Table 5
Percentages of fine particles produced for the studied sediments

	Cheviré	AhAh	RN88 – B10	RN88 – B12	A47 – B5	A47 – B6
% of fine particles	31	15	12	13	21	13

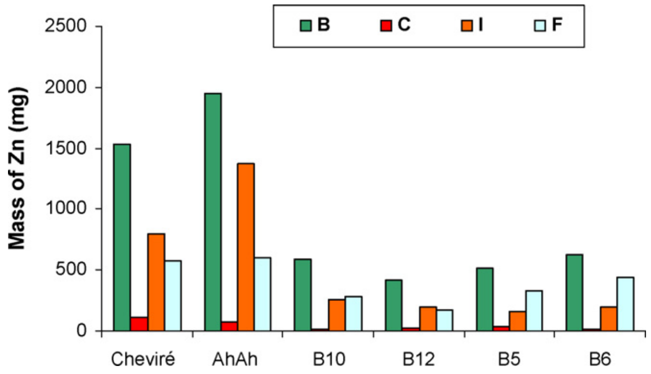

Fig. 3. Example of Zn mass balance for 1 kg of treated sediments. B: bulk, C: coarse, I: intermediate, F: fine.

Table 6
d10, d50 and d90 values for the intermediate fraction both before and after attrition testing (in µm)

	d10	d50	d90
Cheviré			
I	124	718	1467
I_{ATT}	117	551	1310
AhAh			
I	115	404	1208
I_{ATT}	133	338	970
RN88 – B10			
I	96	311	1125
I_{ATT}	93	298	936
RN88 – B12			
I	92	594	1429
I_{ATT}	97	490	1315
A47 – B5			
I	86	391	1235
I_{ATT}	66	280	907
A47 – B6			
I	85	291	1080
I_{ATT}	79	256	787

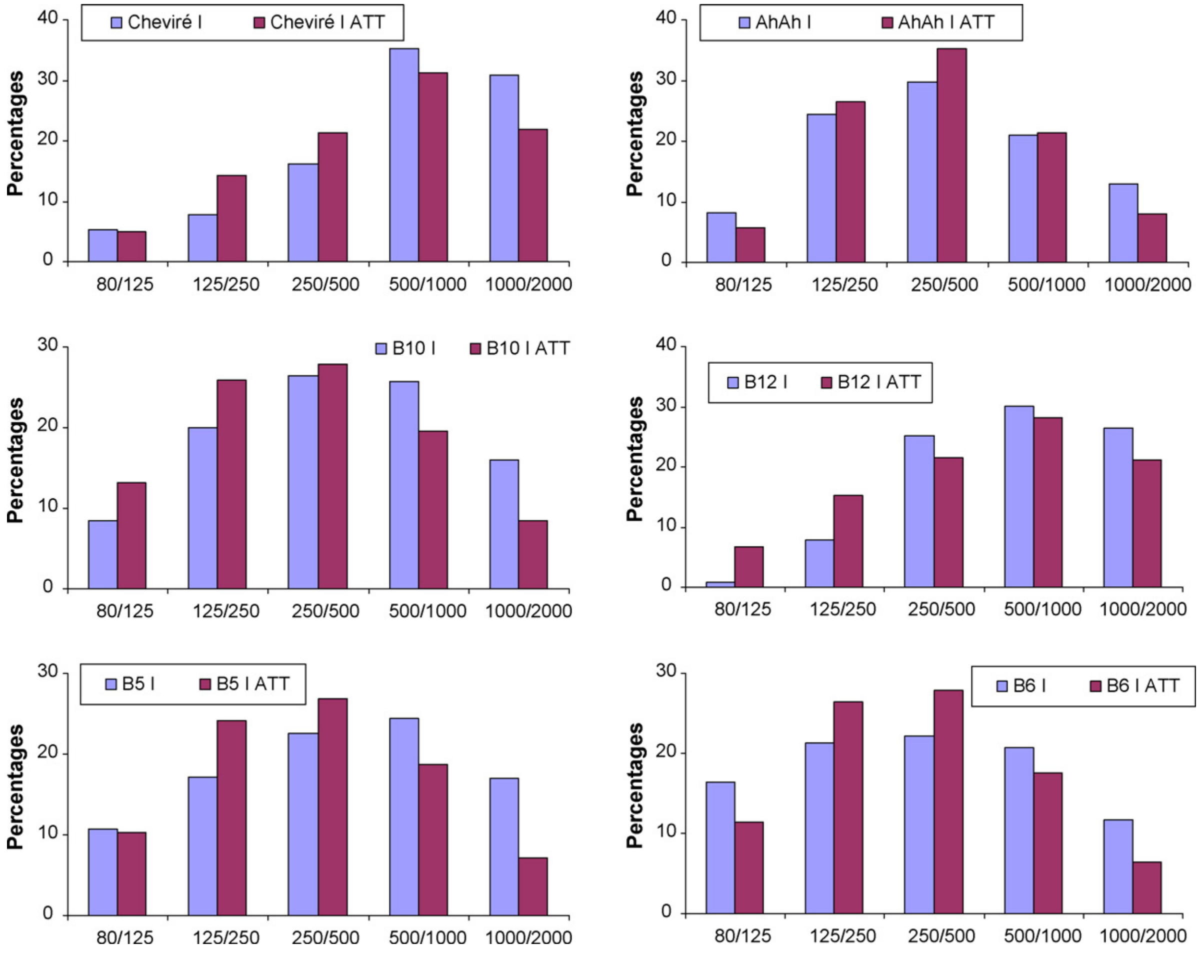

Fig. 5. Evolution in particle size of the intermediate fraction (80 μm to 2 mm) before (I) and after (I_{ATT}) the attrition step for the studied sediments.

3.2.3. Physical comparison between I and I_{ATT}

Attrition scrubbing performance, and therefore the percentages of fine particles produced, is evaluated in Table 5. These particles result from the physical impact and shearing action between particles during the attrition step. Another outcome of this physical treatment is the evolution in particle size distribution within the intermediate fraction.

Table 6 presents the mean particle diameters that represent the grain size diameter for 10%, 50% and 90% of particle size distribution. The median grain diameter, d50, is regularly used as a measure of attrition step efficiency [24]. If the d50 value of particles remains constant during treatment, this would suggest that scrubbing lacks the intensity to produce fine particles or that aggregated particles are absent, which is not the case in this study (Table 5). On the other hand, if d50 varies widely with an exponentially decreasing kinetic, this would suggest that the physical impact is greater and capable of generating a braking effect rather than an attrition step. For all the results shown in Table 6, the mean particle diameter for d50 ranged between 13 μm for B10 sediments and 167 μm for Cheviré sediments. In the case of d90, this range varied from 114 μm for B12

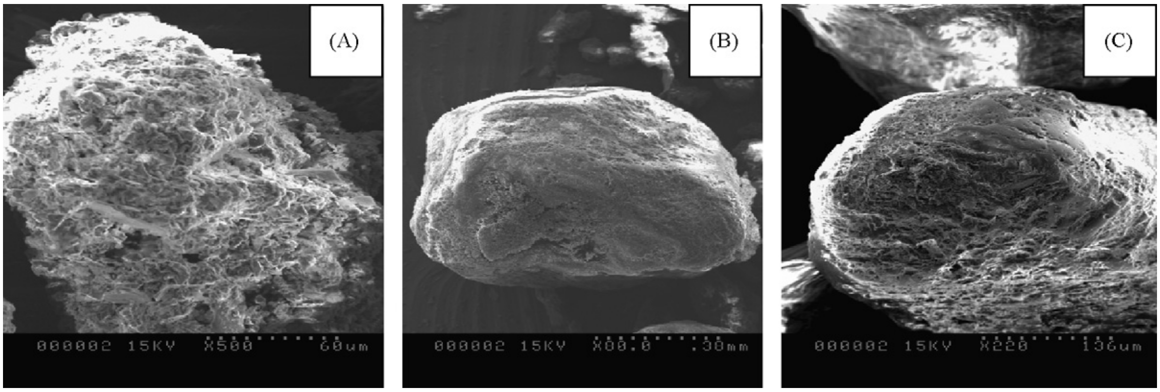

Fig. 6. SEM photograph of a 80 μm to 2 mm fraction particle of the Cheviré sediments: (A) before attrition, (B) after attrition, (C) in this case, the particle is porous and scrubbing does not allow for perfect cleaning of the particle.

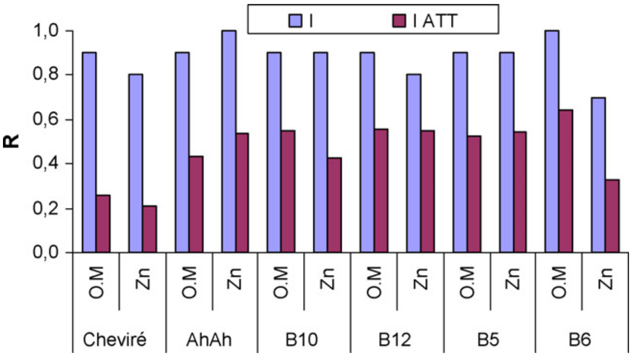

Fig. 7. Ratios (R = mass% of zinc/total mass%) for organic matter and mean trace elements of the intermediate fraction (80 μm to 2 mm) both before (I) and after (I_{ATT}) the attrition step on the studied sediments.

to 328 μm for B5. In contrast, the d10 variation between the results obtained before and after the attrition step is not significant. The evolution in mean particle diameter indicates a positive effect on the particles and eliminates the possibility of inciting a braking action.

The next step consists of examining particle size evolution within the various classes (Fig. 5). To carry this step out, intermediate fractions (I and I_{ATT}) were partitioned into five grain size classes: 80–125 μm, 125–250 μm, 250–500 μm, 500–1000 μm and 1000–2000 μm; for each class, the percentage of particles was determined in order to better examine their evolution.

As seen in Fig. 5, mass percentages in the different size fraction classes lie between the I and I_{ATT} fractions. According to the d90 results, the percentages of the 1000–2000 μm fractions are higher before the attrition test than after, with percentages decreasing from 5% for AhAh sediments to 10% for B5. Except for AhAh, a decrease in percentages is also noted for the 500–1000 μm fractions, reduced from 3% and 6%, for B12 and B5 sediments, respectively.

On the contrary, the mass percentages of the 125–250 μm and 250–500 μm fraction ranges increase after the attrition testing step. For a given fraction, the percentages of particles resulting from attrition of the coarsest fractions are actually greater than the percentage of fine particles produced from this fraction.

The evolution in mass percentages of the 80–125 μm depends heavily on the studied sediment; these percentages increase for B10, B12 and B6, yet decrease for the three other sediments.

A scanning electron microscopy (SEM) study of the 80 μm to 2 mm fraction both before (I) and after (I_{ATT}) attrition was performed in order to confirm the cleaning effect of attrition on the particles (Fig. 6A–C). Fig. 6A shows a particle before attrition: it is coated with aggregates of polluted fines. Following attrition, the particle has been cleaned (Fig. 6B), without aggregates,

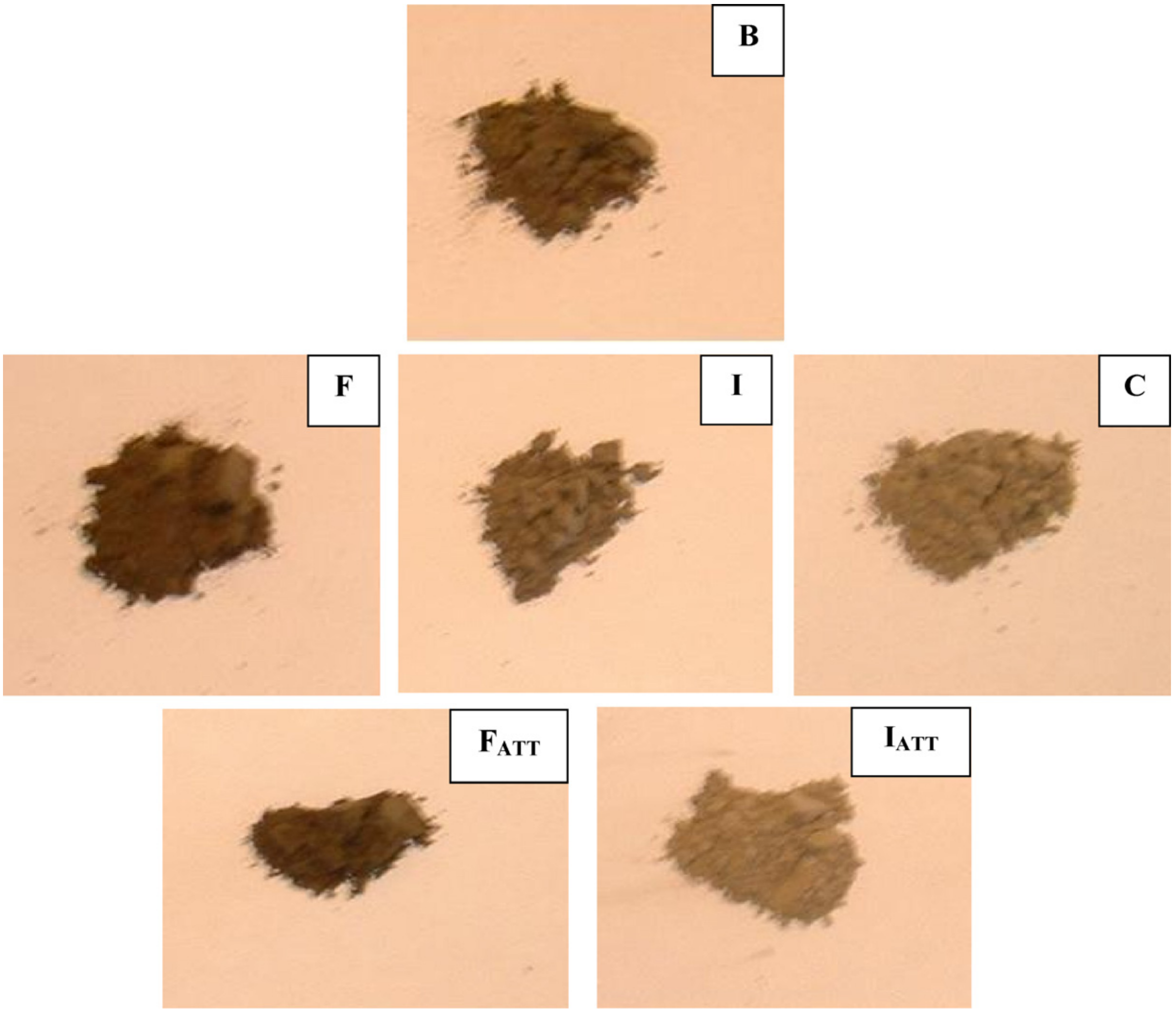

Fig. 8. Photograph of the bulk Cheviré sediment and the various fractions. B: bulk sediments, F: fine particles (<80 μm), I: intermediate particles (80 μm to 2 mm), C: coarse particles (>2 mm), F_{ATT}: fine particles (<80 μm) after the attrition step, I_{ATT}: intermediate particles (80 μm to 2 mm) after the attrition step.

Table 7
Mass percentage, organic matter and R ratios in the three fractions C (>2000 μm), I_{ATT} (60 μm to 2 mm), and F + F_{ATT} (<60 μm) of the Cheviré and AhAh sediments

	D.M.	OM	Cd	Cr	Cu	Ni	Pb	Zn
Cheviré								
>2000 μm	8	0.7	0.6	0.5	0.6	0.6	0.6	0.6
60–2000 μm	50	0.2	0.1	0.5	0.1	0.4	0.4	0.2
<60 μm	38	2.2	2.3	1.9	2.4	2.0	1.9	2.3
AhAh								
>2000 μm	13	0.8	0.3	0.7	0.4	0.5	0.5	0.7
60–2000 μm	74	0.5	0.3	0.8	0.7	0.8	0.6	0.4
<60 μm	11	4.4	6.6	2.8	3.7	2.1	4.4	5.7

underscoring the positive effect of attrition. This technique however is of limited effectiveness when the particle is porous (Fig. 6C), in which case scrubbing does not allow for perfect cleaning of the crusting, and a few aggregates are left on the particle.

3.2.4. Chemical comparison between I and I_{ATT} fractions

As can be seen in Fig. 7, the intermediate fraction (*R* = mass% of pollutant/total mass%) is smaller after the attrition step, for both organic matter and trace metals. Ratio values range from 0.8 to 1 after sieving at 80 μm and are greatly reduced by the attrition step to between 0.4 and 0.8.

Attrition allows isolating the fine particles (F_{ATT}) and generating an intermediate fraction (I_{ATT}) with a degree of pollution 1.3–2.5 times less than after the first sieving. Attrition brings about a very significant reduction in trace elements and organic matter pollution; furthermore, the ratios tend to be similar for trace elements and organic matter, thereby confirming the correlation between organic and inorganic pollution with the potential for chemical bonds occurring between contaminants and the solid, such as reactions with humic matter on both particle and contaminants [8,18].

3.2.5. Conclusion

Screening and attrition allow localizing organic and metallic pollution within fine particles that are either “free” and easily separable by sieving or aggregated; an attrition step therefore serves the purpose of isolation. This polluted fine fraction was isolated, making it possible to reuse the coarse (>80 μm), unpolluted fraction. Fig. 8 shows the effect of sieving and attrition on Cheviré stormwater sediments. The bulk sediments (B) are dark, which indicates a high organic matter concentration. The color of the three fractions (C, I and F) resulting from sieving at 2000 μm and 80 μm is quite contrasted. The coarse fraction C is light-colored, indicating a strong decrease in pollutants, whereas the fine fraction F is black, which suggests pollutant accumulation. According to the ratios (values ranging from 0.8 to 0.9), the intermediate fraction is slightly fairer in color than the bulk sediments; furthermore, attrition process efficiency can be assessed by comparing B pictures with the I_{ATT} and F_{ATT} pictures (see Fig. 8). While the I_{ATT} fraction is light, F_{ATT} is dark and similar to the F fraction. The color of the fines produced corresponds with the chemical analyses and indicates a considerable enrichment of pollutant within this fraction.

3.3. Pilot study

Two stormwater sediments, Cheviré and AhAh, studied previously under laboratory conditions, were also treated in the pilot unit; results are given in Table 7. In comparison with laboratory conditions, many pilot unit parameters differ (see Table 2) and modify the power input into the system [25]. In this case, the lower S2 limit, which determines the percentages of fine particles (F fraction), is fixed at 60 μm. Impeller speed and residence time are also modified, with 402 rpm vs. 2125 rpm and 50 min vs. 3 min, respectively. In contrast with the batch experiments during laboratory testing, treatment is run continuously in the pilot unit. Consequently, only one treatment step takes place; the intermediate fraction (I) and fine fraction (F) do not get characterized. The results of mass percentage, organic matter and R ratios are given in Table 7 for the three fractions derived: C (>2000 μm), I_{ATT} (60 μm to 2 mm), and F + F_{ATT} (< 60 μm).

For Cheviré and AhAh sediments, the >2000 μm particles make up 8% and 13% of the bulk samples respectively and display a ratio of 0.6 for organic matter and 0.7 as a mean for trace elements. These fractions are slightly depleted in both organic and inorganic pollutants.

The intermediate fractions make up 50% and 74% of the bulk sediments for Cheviré and AhAh sediments and are highly depleted in pollutants. For Cheviré sediments, the ratios equal 0.2 for organic matter and range from 0.1 to 0.5 for trace elements; they are slightly higher for the AhAh intermediate fraction, with ratios of 0.5 for organic matter and up to 0.8 for Cr and Ni. Although the experimental conditions differ between the laboratory and pilot tests, intermediate fraction ratios are similar with a difference of less than 0.1.

The <60 μm fractions from pilot treatment amount to 38% for Cheviré and 11% for AhAh. Furthermore, this fraction is heavily polluted, with organic matter ratios ranging from 2.2 for Cheviré to 4.4 for AhAh and trace element ratios from 1.9 (chromium) to 2.4 (copper) for Cheviré and from 2.2 (nickel) to 6.6 (cadmium) for AhAh.

4. Conclusion

Ponds must be built in order to limit water level rises and subsequent flooding downstream, yet the cumulative volumes of sediment increase and cleaning-out proves necessary in order to maintain pond efficiency. Moreover, the accumulated sediments may contain high organic matter and heavy metal contents.

In this study, physical laboratory and pilot treatments have been proposed in the aim of developing a pilot unit for the decontamination of stormwater sediments.

A ratio defined as (*R* = mass% of pollutant/total mass%) was introduced to quantify the combined effect of sieving and attrition. Screening and attrition have made it possible to concentrate pollutants into the fine particles (*R* ranges from 1.8 to 3.6 in the <80 μm laboratory fractions and from 1.9 to 6.6 in the <60 μm pilot fraction). This step has provided an undeniable advantage for subsequent sediment treatment. The polluted fine fraction was isolated to allow for reuse of the coarse (>60 μm for pilot unit), unpolluted fraction. This study has shown that up to 70% of a sediment can be reused after the proposed physical treatment. Geotechnical and economic criteria have also been taken into account in developing the pilot unit [19].

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