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1 To what extent can micro- and macroplastics be
2 trapped in sedimentary particles? A case study
3 investigating dredged sediments.

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11

12 **Abstract**

13 Plastic wastes and their fragments (microplastics, MPs <5 mm) represent a global, persistent,
14 and ubiquitous threat to ecosystems. Their sources, transfers and fates are still poorly
15 understood, especially in rivers. To fill this gap, sediments were collected from two dredging
16 disposal sites along the Aa River (France). Four pits were dug, and triplicate samples were
17 obtained at four depths (down to 140 cm). The sediments were sieved to 5 mm to collect
18 macroplastics (MaPs). MPs were separated from the sediment based on density using a NaI
19 solution (1.6 g/mL). Suspected plastics were analyzed with Fourier Transform InfraRed
20 (FTIR) spectroscopy. The studied sediments were found to be widely contaminated with
21 concentrations ranging from 0.97 to 77 MaPs/kg and from 0.78 to 2800 MPs/kg, which were
22 one to four orders of magnitude lower than those in most polluted European riverbeds. The
23 MaPs were principally PE, PP, PS and PVC films, whereas the MPs were mainly PA and PES
24 fibers. The plastic concentrations and features of the two sites, which were filled at two
25 different times, differed. Several factors occurring before and after dredging operations may
26 explain these discrepancies. Nevertheless, no relationships with the sediment features were
27 noted, and thus, one major driving force could not be identified. At the site scale, more than 1
28 ton of plastic could be stored. In conclusion, this study highlights the importance of dredged
29 sediments for past plastic pollution studies and global plastic budget estimations.

30 **Introduction**

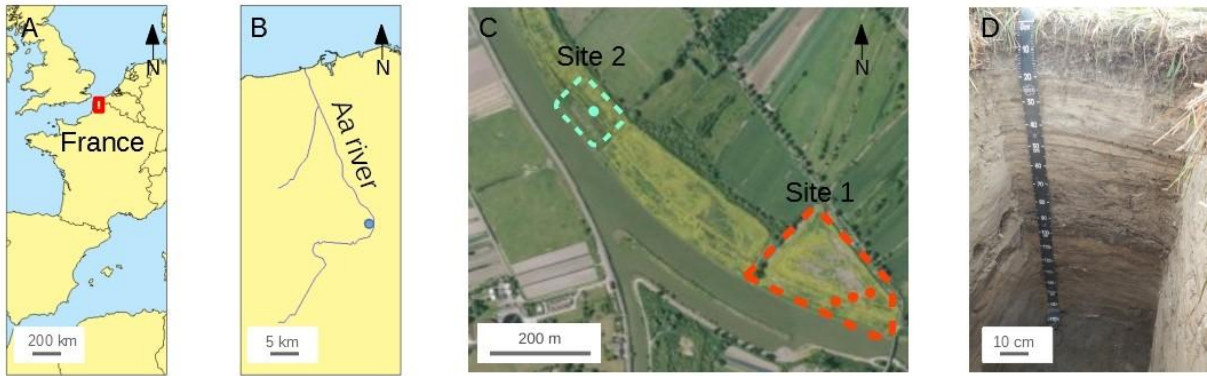
31 Anthropogenic litter, notably plastic pollution, is one of the most visible, ubiquitous and
32 durable threats to terrestrial ecosystems^{1,2}. Plastics can enter a broad range of animal bodies,
33 including humans, through ingestion, breathing or trophic transfer³⁻⁵ and are frequently
34 associated with an extensive range of chemical substances⁶⁻⁸. This is particularly true for
35 small pieces of plastic, commonly called microplastics (MPs <5 mm)⁹. These hazards are
36 reinforced by the slow degradation of plastic, especially in environments with low UV
37 radiation, temperature and oxygen, such as the deep sea and sediments¹⁰.

38 Data on plastic debris distributions in terrestrial environments are sparse compared with
39 those in marine environments¹¹. However, considerable amounts of anthropogenic litter sink
40 in or transit through freshwater systems¹². A limited number of studies have been conducted
41 on plastic deposited in riverbeds¹³. Notably, to our knowledge, only one investigation has
42 been conducted on MPs trapped in dredged sediment¹⁴. These materials can provide
43 qualitative and quantitative information on past pollution. Because long-term monitoring is
44 lacking, studying sediment records is notably interesting for unraveling the dynamic
45 accumulation of MPs. In particular, dredged sediment may provide a snapshot of the pollution
46 at a certain moment in time, because sediment removal stops hydrologic processes. This
47 information is necessary for understanding the settlement of plastics, improving global
48 budgets and predicting forthcoming trends. In addition, terrestrial deposit sites are often easier
49 to sample than bed sediment. The challenging objectives of our study were to examine the
50 quantitative (*i.e.*, density) and qualitative (*i.e.*, size, shape and polymer composition)
51 distributions and properties of MaPs and MPs within sediments deposited during two periods.
52 Our investigations provide relevant results concerning the knowledge of past plastic
53 contamination in dredged sediments and open the way for further investigations in the near
54 future.

55 **Methods**

56 ***Sediment collection***

57 Sediments were sampled in May 2019 at two sites in a dredging disposal area (Figures 1A,
58 B and C). The sites (Site 1: 2004; Site 2: 2016) were filled with dredged materials from the
59 Aa River, a North Sea coastal river with a small sparsely populated and industrialized
60 drainage catchment area^{15,16} (see Supporting Information (SI) for further details). At the first
61 site, three pits (1.5 × 1.5 m) were dug 30 m apart to a depth of 1.5 m (Figure 1D). Overall, the
62 sediments were coarse but with considerable horizontal (between pits) and vertical (between
63 depths) heterogeneities (SI Table S1 and Figure S3). At the second site, only one pit (1.5 ×
64 1.5 × 1.5 m) was dug, and the sediments were fine and homogeneous. The sediments were
65 collected with a metal trowel at four depths (0-10, 20-30, 80-90 and 130-140 cm; see SI for
66 details).



67

68 **Figure 1.** Location maps and pictures of the study area. A) General map of France. Red
69 rectangle shows the Aa River location. B) Sampling site (circle) along the Aa River Basin. C)
70 Aerial pictures of the sampling sites. Dashed polygons show the borders of each site, and
71 circles indicate the positions of the pits. D) Picture of a pit at site 1.

72 ***Preparation of the samples prior to analysis***

73 MaPs were extracted using a 5 mm metal sieve (see SI for details). After removing most of
74 the organic matter with H₂O₂ (3%), the MPs were separated from the sediment using NaI (1.6
75 g/mL) density-based extraction according to Claessens *et al.*¹⁷, which was adapted to our
76 samples (see SI for details). Finally, the plastics were observed, photographed, measured and
77 sorted into five shape categories using a dissecting stereomicroscope (SI Figures S1 and S2).

78 ***FTIR spectroscopy and granulometric analysis***

79 A total of 62 suspected MaPs (13% of the sorted particles) and 166 suspected MPs (14%)
80 were analyzed by Fourier Transform InfraRed (FTIR) spectroscopy to determine whether they
81 were actually plastics and, in this case, to determine their polymeric composition (see SI for
82 details). Large particles (>500 µm) were analyzed by FTIR-ATR spectroscopy, whereas
83 fibers, due to their small volumes, and other small particles (between 500 and 150 µm) were
84 analyzed by micro-FTIR spectroscopy.

85 The sediment particle size distribution (between 0.04 and 1000 µm) was determined for
86 each sample following standardized laser diffraction methods (see SI for details).

87 ***Data analysis***

88 FTIR analysis and contamination controls were used to correct the initial sorting and
89 accurately identify true MaPs and MPs in our samples. First, the abundances of fibers in the
90 controls (the only shape observed) were subtracted from the initial count. Blank-corrections
91 represented less than 5% of the MP initial counts. Then, for each shape category, an identified
92 plastic ratio was accordingly applied. This ratio was calculated by dividing the number of
93 particles confirmed to be plastic by FTIR analysis by the total number of items analyzed and
94 visually described as “potential plastics”. All the MaP and MP contents and the relative
95 contents of the shapes given in the following text, figures and tables are based on the FTIR-
96 and blank-corrected results. Ultimately, the concentrations of MaPs and MPs were estimated

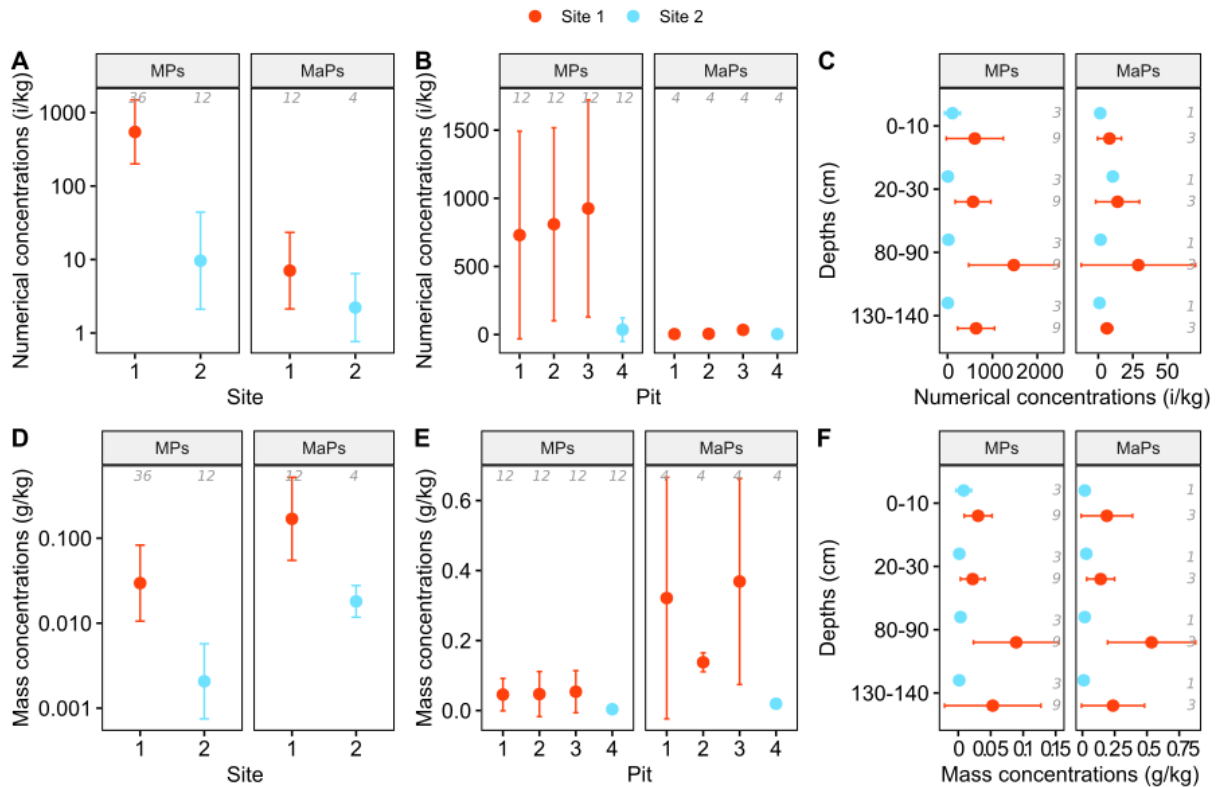
- 97 by dividing the corrected numbers and mass of plastic items by the weight of the dry sediment
- 98 processed (items and mg/kg; for statistical analysis details, see SI).

99 **Results**

100 *Plastic quantities*

101 Both macroplastics (MaPs) and microplastics (MPs) were detected in all the sediment
102 samples. The concentrations were widely distributed over three to five orders of magnitude
103 (SI Table S2). The MaP concentration ranged from 0.93 to 77 items/kg and from 11 to 760
104 mg/kg. The MP concentration varied between 0.78 and 2,800 items/kg and between 0.38 and
105 240 mg/kg.

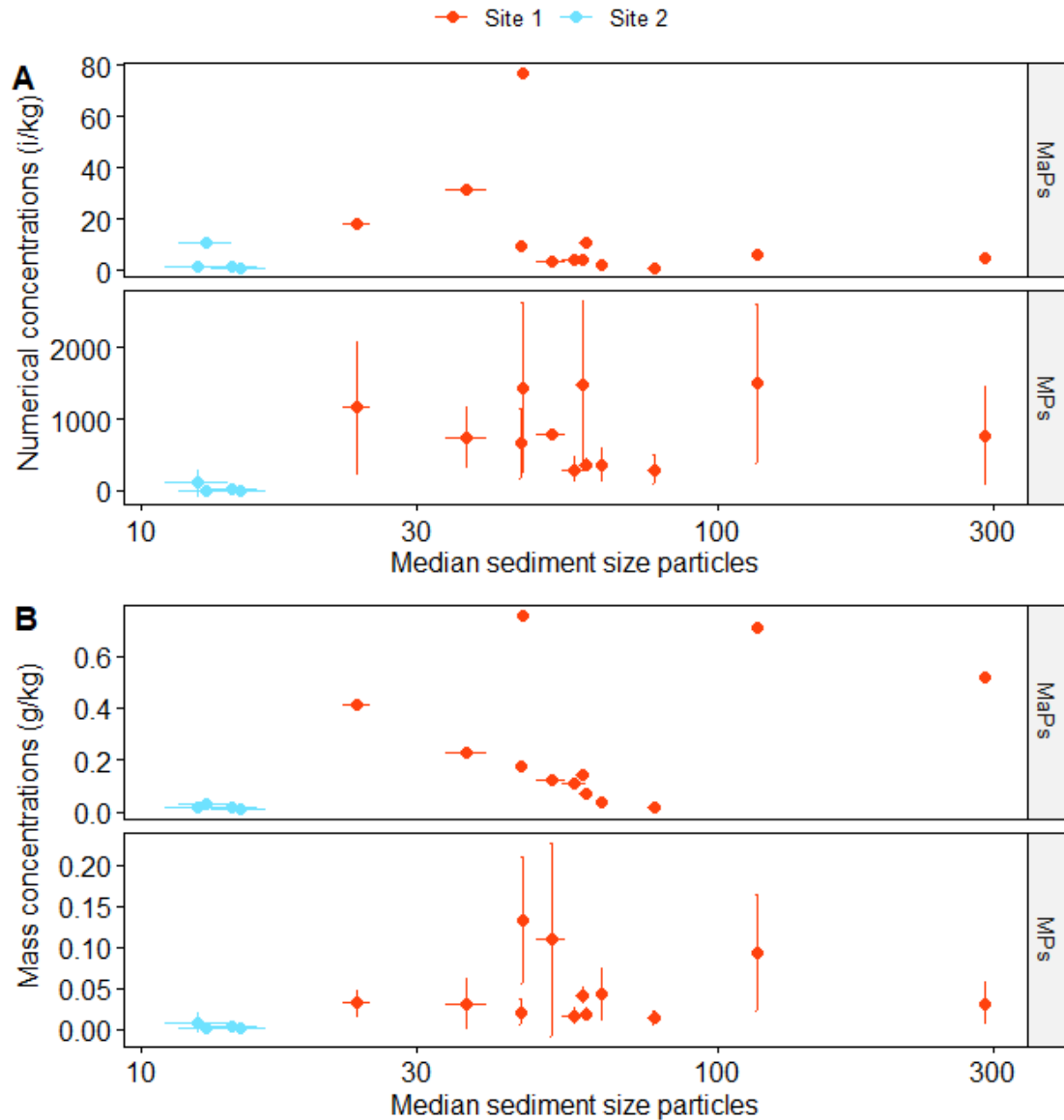
106 The concentrations, except the MaP numerical concentrations, at the two sites were
107 significantly different (Wilcoxon test; Figures 2A and D and SI Table S3). At site 1, no
108 significant differences were observed in the MP concentrations of concomitant samples
109 collected 30 m apart (SHR test; Figures 2B and E). However, the MaP numerical
110 concentrations at the pits were significantly different (SHR test; Figures 2B and E). The
111 vertical patterns of the MPs and MaPs were relatively similar at site 1, but not at site 2
112 (Figures 2C and F). At both sites, however, the concentrations at the different depths were not
113 significantly different, except MP numerical concentrations (Kruskal-Wallis and SHR tests).



114
 115 **Figure 2.** Mean plastic concentrations per kg of dry sediment (item/kg and g/kg). A, D)
 116 Concentrations at both sites expressed in items/kg (A) and g/kg (D) (the horizontal axis is
 117 scaled by a logarithm base 10 transformation). B, E) Concentrations in each pit at both sites
 118 expressed in items/kg (B) and g/kg (E). C, F) Concentrations at each depth for both sites
 119 expressed in items/kg (C) and g/kg (F). The bars represent the standard deviation from the
 120 mean. The gray italic numbers indicate the number of samples.

121 ***Covariation between MaPs, MPs and environmental factors***

122 No relationship was observed between the concentration of plastics and the sediment
123 features, such as the percentages of sediment smaller than 2 (clay), 20 (silt) and 200 μm
124 (sand) or the particle size corresponding to 10%, 25%, and 50% of the accumulated volume of
125 sediment (see, for instance, Figure 3). At site 1, the numerical and mass concentrations
126 covaried significantly for both the MPs and MaPs (Pearson test; SI Figure S5A). Similarly,
127 the masses of the MPs (average per sample) and MaPs exhibited a positive and significant
128 linear relationship, in contrast to the numerical concentrations (Pearson test; SI Figure S5B).
129 When the concentrations at site 2 were added to the data set, the p-values of the linear
130 regressions were slightly improved, but the overall results remained similar (Pearson test).



131

132 **Figure 3.** Relationships between the plastic concentrations and sediment features. Numerical

133 (A) and mass (B) concentrations are plotted as functions of the median sediment grain sizes of

134 the macroplastics (MaPs) and microplastics (MPs). The concentrations are expressed in

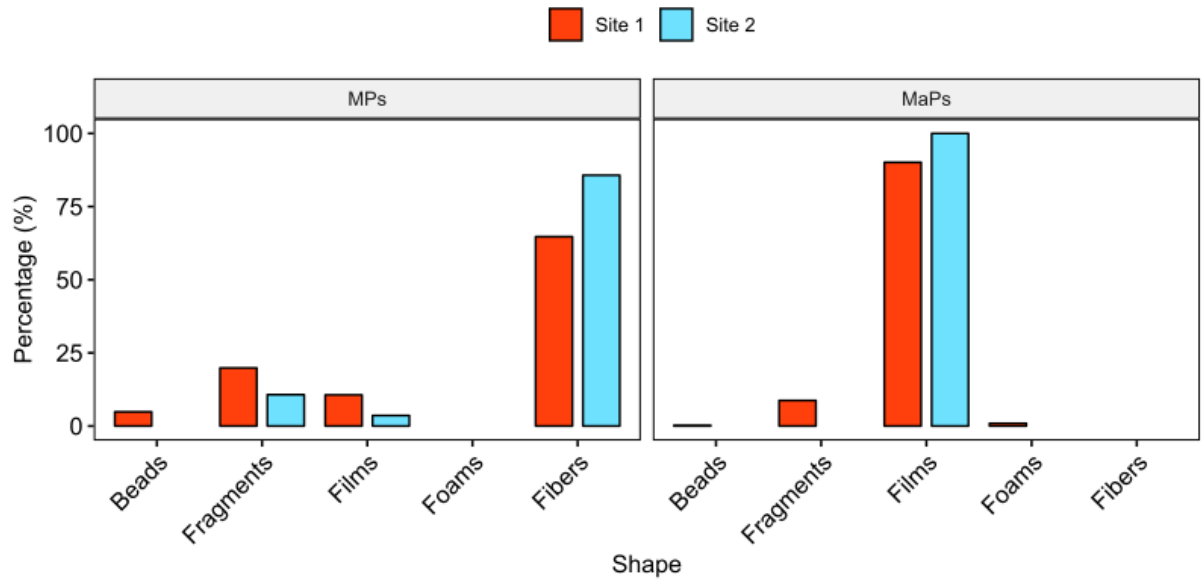
135 items/kg (A) and g/kg (B). The horizontal axis is scaled by a logarithm base 10

136 transformation.

137 *Plastic shapes*

138 Due to the large number of shape categories considered (SI Figures S1 and S2), data from
139 independent samples were pooled within each study site. A similar distribution was observed
140 at both sites, but the distributions of the MaPs and MPs were different. For the MaP size class,
141 films were the most abundant shape found at site 1 (90%; Figure 4) and the only shape
142 observed at site 2. Fragments were the second most abundant shape by number (9%) at site 1.
143 The amounts of foams and microbeads were negligible (<1%) at both sites. No MaP fibers
144 were observed at either site.

145 For the MP size class, fibers were the most abundant shape found at both sites (Site 1: 65%;
146 Site 2: 86%), followed by fragments (Site 1: 20%; Site 2: 11%) and films (Site 1: 11%; Site 2:
147 4%; Figure 4). Microbeads were less common (<5%) at site 1 and not found at site 2. No MP
148 foam was observed at either site.



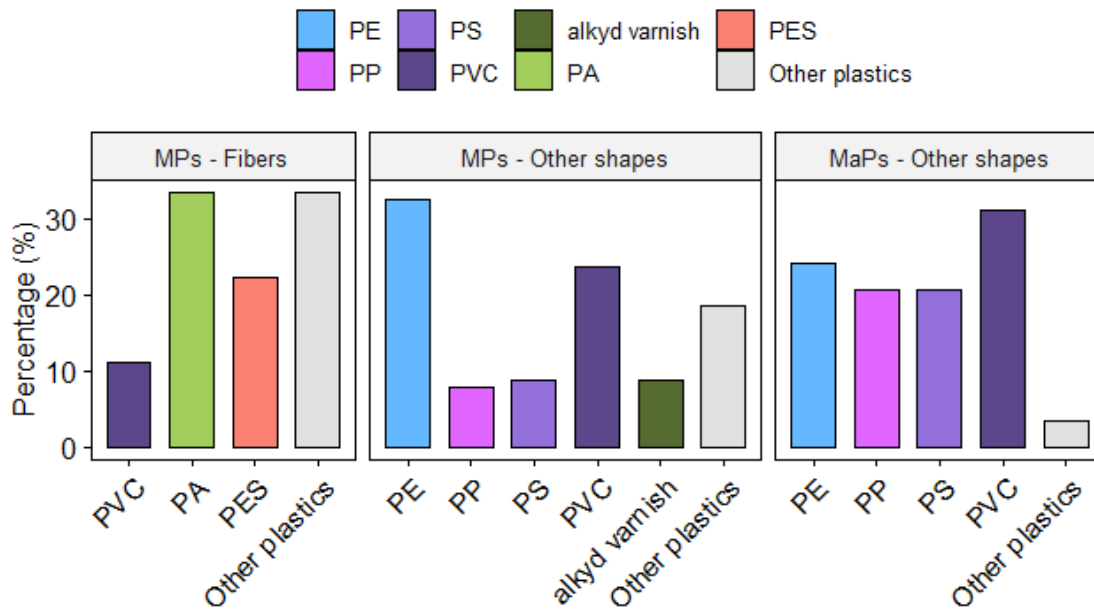
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150 **Figure 4.** Shape distributions of the microplastics (MPs) and macroplastics (MaPs) found at

151 both sites.

152 ***Polymer composition***

153 Twenty different polymer types were identified from all the sediment samples. Only a
154 limited number of suspected MaPs were not synthetic polymers (2/60 particles identified by
155 FTIR spectroscopy; 60/62 particles were identified) but wood or cellulose (SI Figure S4).
156 Therefore, the rate of correctly identified plastics was high (97%) for large particles.
157 However, the results obtained by FTIR spectroscopy confirmed the necessity of performing
158 plastic polymer analysis on small plastics, particularly fibers, for correcting the data. Indeed,
159 we found that less than half (9/26 particles identified) of the binocular-sorted MP fibers were
160 actually plastic. This low percentage (35%) of plastic is likely related to the difficulty in
161 discriminating between plastic fibers and cotton and plant fibers with binoculars or a
162 dissecting stereomicroscope. For the plastic fibers, polyamide (PA), polyester (PES) and
163 polyvinyl chloride (PVC) were the three most abundant polymers (33, 22 and 11%,
164 respectively; Figure 5). In contrast, the identification of other plastic shapes (films, fragments,
165 foams and beads) was mostly successful (114/134 or 85%; 134/140 particles were identified).
166 For those shapes, the polymers were mainly the same for both plastic size classes (Figure 4).
167 The MaPs were principally made of PVC (31%), polyethylene (PE; 24%), polypropylene (PP;
168 21%) and polystyrene (PS; 21%), and the MPs (other than the fibers) were mainly composed
169 of PE (33%) and PVC (24%).



170

171 **Figure 5.** Synthetic organic polymer compositions of the MaPs and MPs found at both sites.

172 Shapes: fibers and other shapes (fragments, foams, films and beads). Polymers: polyethylene

173 (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), alkyd varnish,

174 polyamide (PA), polyester (PES), other plastics (*e.g.*, polyethylene terephthalate,

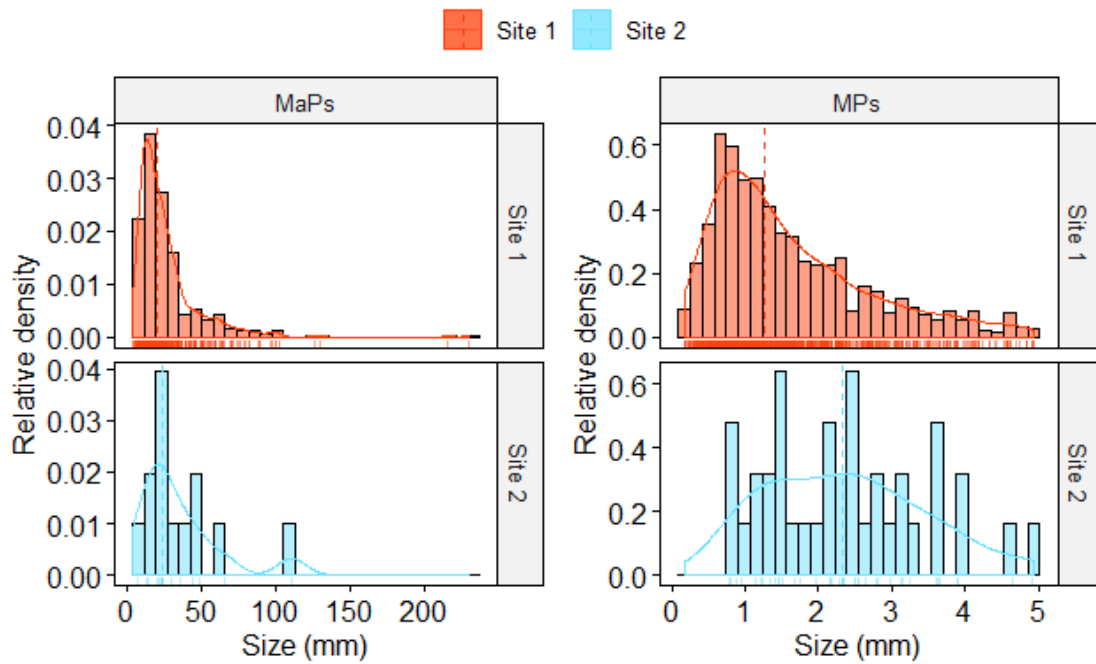
175 polyurethane, polyacrylamide), as determined by FTIR spectroscopy analysis. See details in

176 the FTIR spectroscopy section for polymer identification and SI Figure S4 for the percentages

177 of plastic, unidentified and non-plastic sorted particles.

178 ***Size***

179 After all the sorted particles were measured, no marked differences were observed between
180 the MaP and MP size distributions of the two sites (Figure 6). The MaPs ranged from 5 to 230
181 mm, and the MPs ranged from 167 to 4939 μm . The MaPs exhibited a unimodal distribution
182 skewed towards smaller size classes, and the medians were approximately 20 (site 1) and 24
183 mm (site 2). The MP size distribution, which had a median of approximately 1 mm, was
184 similar to the MaP size distribution at site 1. At site 2, the MPs exhibited a rather stochastic
185 distribution. Only a few particles were observed in the size classes near the sieve meshes
186 (MaPs: 5 mm; MPs: 125 μm), probably because the size was measured based on the longest
187 dimension. These particles could pass through the sieve by their narrowest dimensions and
188 were therefore not collected and counted.



189

190 **Figure 6.** Relative densities of the macroplastics (MaPs) and microplastics (MPs) within each
 191 size class at each site. Size: longest dimension of the items. Density: number of plastics
 192 within a size class, scaled to 1. Width of the size class bars: 8 mm (MaPs) and 0.17 mm
 193 (MPs). The lines show the density curves, and the dashed lines indicate the median values.

194 **Discussion**

195 ***Plastic pollution in the Aa River***

196 In dredged sediments, buried plastics could indicate the average levels of the past plastic
197 pollution of riverbed sediments. At the two studied sites, sediments were deposited at an
198 approximate interval of a decade. The plastic quantities were more substantial at site 1
199 (deposit date: 2004) than at the more recent site 2 (deposit date: 2016). Dissimilarities in the
200 shape partitions were also observed, whereas differences of the polymer and size distributions
201 were limited. The plastic quantities and features could change both before and after deposition
202 through distinct processes. Before dredging operations, sediments and their pollutants are
203 predominantly affected by river inputs, flow variations, sedimentation rates, resuspension
204 events, *etc.* After the deposition of dredged sediments, the sediments evolve into new soil
205 with the development of pioneer vegetation, as observed at our study site, and other
206 mechanisms can occur (*e.g.*, slow reoxidation processes, infiltration, bioturbation,
207 bioabsorption, *etc.*).

208 Before sediments are transferred to dredging deposition sites, they accumulate plastics that
209 sediment into the riverbed. On the one hand, the deposition of plastics in riverbeds depends
210 on the pool of plastics released to the environment, which is related to the local uses of
211 plastics and waste management. Plastic production and consumption have increased since the
212 middle of the twentieth century⁹. In developed countries, waste management has concurrently
213 improved over the last decade. On the other hand, similar to the deposition rate of other
214 suspended matter¹⁸, the plastic deposition rate may have changed due to a hydrodynamic
215 change (*i.e.*, course of the river and/or river flow velocity)¹⁸. Accordingly, the dissimilarity of
216 the sites in terms of both the sediment features and plastics may be related. Nevertheless, the
217 mechanisms that govern the settling process of plastics into bed sediments are imperfectly

218 known. Moreover, the distribution of plastic debris is highly heterogeneous, even at a scale as
219 small as a few meters¹⁹⁻²².

220 After dredging operations, the evolution of synthetic polymers over time within deposited
221 sediments, similar to soils, remains largely unknown²³. In our case, the development of
222 pioneer vegetation is accompanied by other processes (*e.g.*, slow reoxidation processes,
223 rainwater infiltration, bioturbation, bioabsorption). Therefore, the dredged sediments do not
224 necessarily reflect the initial contamination state of the river. The conditions of the subsurface
225 are rather stable, with moderate temperatures and no UV radiation, which is unfavorable for
226 degradation¹⁰. Nevertheless, the initial quality and quantity of plastic may change, at least due
227 to biodegradation²⁴. In addition, initial plastic distributions can also change if particles
228 migrate through infiltration and bioturbation²⁵⁻²⁷. The dredging processes in channeled rivers
229 also result in an important perturbation and resuspension of settled particles. An unknown
230 fraction of resuspended particles, including plastics, may finally migrate downstream in the
231 river, reducing the total amount of plastic particles transferred to the deposition site.

232 At both sites, light plastic polymers were observed in non-negligible quantities (Figure 5).
233 Among them, PE, PP and PS were logically the most abundant. They were among the most
234 produced polymers during the last decade²⁸. However, they have a density below or slightly
235 higher than 1 g/cm³ and should float in freshwater systems. Physical and biological processes
236 can force buoyant plastics to sink²⁹, but the observations needed to estimate their occurrences
237 are lacking. In addition, after this extended period of storage, the most breakable plastics may
238 have been fragmented through degradation, becoming smaller than our detection size limit.

239 Films were predominant in the MaPs, whereas they constituted a negligible fraction of the
240 MPs (Figure 4). Similar to the ratio of polymers, a rather similar shape ratio could be
241 expected along the plastic size range, from the longest MaPs to the smallest MPs, with the
242 exception of fibers, which are primarily micrometric in size and consequently absent from the

243 MaPs³⁰. These dissimilar patterns can indicate differences in the fragmentation rates of the
244 shapes or in the sources. Plastic films are used in packaging or bags, which are short-life
245 objects released into the environment in micrometric sizes. Indeed, they are among the most
246 frequent MaPs found at river surfaces³¹. Fragments may be more prone to surface layer
247 fragmentation, resulting in the release of smaller pieces that are not detectable by our
248 procedure.

249 The size distribution at site 1, especially that of the MPs, was subtly shifted towards the
250 smallest dimension compared with that at site 2, a pattern, which could indicate stronger
251 degradation and is consistent with the historical context of the samples. Nonetheless, many
252 other factors may affect the size distribution, including shape and polymer discrepancies.

253 By multiplying the median concentrations of the plastics (SI Table S2) by the volume of the
254 sediment, we could roughly estimate that 3×10^{10} items ($>125 \mu\text{m}$) or 9 tons of plastics are
255 trapped within site 1 ($3.8 \times 10^4 \text{ m}^3$) and 5×10^8 items or 0.9 tons are trapped in site 2 ($1.5 \times$
256 10^4 m^3). In France, more than $1.4 \times 10^6 \text{ m}^3$ of riverbed sediments are dredged every year³².
257 Plastic budget estimations do not currently incorporate those sections. Deposit sites constitute
258 ultimate plastic sinks, which, unlike riverbeds, are unaffected by flooding and, if not
259 perturbed by human activities, will persist. Once deposited, dredged sediments evolve into
260 new soil, and the presence of plastics may have a significant and durable impact on soil
261 ecosystem development³³.

262 ***External forcing of the plastic distribution within dredged sediments***

263 As indicated above, plastics trapped in dredged sediments are not directly comparable to
264 their counterparts settled in riverbeds. Within watersheds, plastic distributions depend on
265 various factors, such as hydrology and human activities³⁴. When dredged sediments are
266 deposited at storage sites, this initial distribution is probably perturbed. First, sediments are
267 taken out of the river and put in an intermediate container (*e.g.*, boats or trucks), which tends

268 to homogenize the grain size distribution and may result in the incorporation of new plastics
269 from the container (*i.e.*, contamination). Then, the sediments are deposited at storage sites
270 using pumps, which creates horizontal and vertical granulometric gradients. In fact, because
271 large grains settle more rapidly, the size of the sediments gradually decreases from the pump
272 to the opposite corner of the site and from the bottom to the surface.

273 Because the data at site 2 are limited, only the variability at site 1 is discussed. At this site, 3
274 pits were dug 30 m apart. They were deposited during the same operation and came from the
275 same river localization. Due to the filling process, the grain size at site 1 gradually decreased
276 from pit 1 to pit 3 (south to north; Figure 1 and SI Figure S3). No covariations between the
277 plastic concentrations and grain size distributions were observed (Figure 3). Plastics and
278 sediments may behave and settle differently because of differences in the shape, size and
279 density distributions³⁵. More precisely, sediment shapes range from nearly spherical (*e.g.*,
280 mature siliciclastic sediment) to nearly flat (*e.g.*, muscovite, biotite), MaPs are mostly films
281 (~2D shape), and MPs are mainly fibers (elongated and thin cylinders). The medians of the
282 sediment sizes ranged from 10 to 100 μm , the MaP median was approximately 20-24 mm,
283 and the MP median was 1 mm. Finally, the volumetric mass density of the sediments was
284 greater than 2 g/cm^3 , and the densest polymers observed (PVC and PET) had a density of 1.4
285 g/cm^3 .

286 Even if the plastics and sediments features are different, the plastic distribution could still
287 follow the same gradient as the sediments, with larger, denser, more spherical and less
288 weathered plastics settling deeper and closer to the pumps and thinner, lighter, more irregular
289 and more weathered plastics settling at or near the surface and further from the pumps^{35,36}.
290 This behavior indicates an inverse relationship between MPs and MaPs, *i.e.*, samples from the
291 beginning of the site contained large amounts of MaPs but few MPs, whereas few MaPs but
292 numerous MPs would be observed at the opposite end. Therefore, the mass and numerical

293 concentrations should follow an inverse trend. However, a covariation between the masses of
294 the MPs and MaPs was observed (SI Figure S5B), suggesting either similar deposition
295 processes or the *in situ* degradation of MaPs to MPs. In any case, this relation could be
296 extremely practical in large-scale investigations. Indeed, MaPs are easily measurable and
297 could be used as a fingerprint to indicate the probable level of pollution by MPs. A
298 covariation between the mass and number was also observed, suggesting a homogenized pool
299 of plastics at the site (SI Figure S5A).

300 The plastic distribution in freshly dredged sediments, *i.e.*, just after the filling operation,
301 might also change. Dredged sediments, similar to soils, evolve under the influences of
302 external forcing. Water infiltration is one external force that may transfer particles from the
303 surface to the bottom, and slightly higher concentrations were observed 1 m below the
304 surface. Waldschläger and Schüttrumpf²⁵ suggest that the infiltration of plastics larger than
305 100 μm (*i.e.*, all plastics observed in this study) may occur in soils. Nevertheless, their
306 experimental conditions (4600 mL/min of water flow for 1 hour through a 194 mm internal
307 diameter column filled with glass spheres) were drastically different from the natural
308 processes that occur in dredged sediments. Bioturbation may also vertically transfer particles.
309 Rillig *et al.*²⁷ experimentally demonstrated that bioturbation could influence the plastic
310 distribution, but the occurrence of this process in the natural environment remains largely
311 unknown.

312 ***Levels of plastic pollution in European watersheds***

313 To our knowledge, only one study on plastic buried in dredged sediment has been
314 reported¹⁴. Consequently, our results can be compared more significantly with studies of
315 actual riverbed sediment, but direct comparisons should be made with caution. As previously
316 mentioned, sediment dredging and deposition operations may change the initial riverbed
317 plastic concentrations.

318 Likewise, no data are available for MaP concentrations in riverbed sediments in European
319 watersheds. The MP concentrations measured at the two sites varied between 9×10^{-1} and $3 \times$
320 10^3 items/kg, corresponding to the lowest range of MP concentrations measured in various
321 European riverbed locations to date (Table S4)^{1,19,37-39}. Concentrations within the same order
322 of magnitude should be considered, in a first approximation, as similar. Indeed, sample
323 collection and treatment, especially visual sorting and FTIR validation, potentially create
324 noticeable differences between studies. Horton *et al.*¹ found moderate concentrations (3×10^2
325 items/kg) in the Thames River (United Kingdom; UK), despite their focus on larger MPs (>1
326 mm). In other studies with similar concentrations to those in found in our study, lower
327 percentages of fibers (<25%) were observed. On average, fibers accounted for 65% (site 1)
328 and 86% (site 2) of all the MP items collected in our study. They were also predominant at the
329 bottom of the canals in Amsterdam (Netherlands)⁴⁰ and reached up to 75% of the MPs in the
330 riverbed sediment of the Ebro River (Spain)⁴¹. In both studies, the observed concentrations
331 were one order of magnitude higher than ours. The concentrations observed in the Irwell and
332 Mersey catchments (UK; 7×10^4 items/kg), the Roter River (Germany; 5×10^4 items/kg) and
333 the Rhin River (Germany; 10^5 items/kg) were two orders of magnitudes higher, but a
334 negligible amount of fibers was detected (<10%)^{18,34,42}, and these studies had a lower size
335 limit (<50 μ m). Note that Frei *et al.*⁴² and Mani *et al.*¹⁸ used a semi-automatic μ FTIR
336 procedure to analyze very small MPs.

337 Plastic fibers are also predominant in numerous other environmental settings, such as
338 wastewater, atmospheric fallout and deep-sea sediment⁴³⁻⁴⁵. Textiles have been pinpointed as
339 a major source of synthetic fibers³⁰, but they can also originate from fishing lines and
340 gear^{46,47}. Notably, one major pathway for MPs to reach riverbed sediment is effluents from
341 wastewater treatment plants (WWTPs). Indeed, WWTPs receive wastewater from washing
342 machines, which can emit up to 700,000 fibers during a single wash³⁰. Even when the

343 removal efficiency is high (up to 98%)⁴⁵, the treated effluent flowing into rivers still contains
344 massive amounts of MPs. Moreover, synthetic fibers are partly trapped in sewage sludge,
345 representing a supplementary source to agricultural watersheds⁴⁸.

346 Twenty distinct polymers were observed, but six of them (*i.e.*, PE, PP, PS, PA, PES and
347 PVC) accounted for more than two-thirds of the total. They are among the most produced
348 polymers⁴⁹, and massive amounts of them are also found in other European riverbeds (Table
349 S4). Horton *et al.*¹ observed a significant contribution of dyes (62%) to their polymer pool in
350 the Thames River (UK) and a negligible proportion of low-density polymers (PE, PP and PS
351 $\leq 5\%$). Low-density polymers represent more than half of the polymers detected in the MP and
352 MaP fragments, films, foams and beads in our study. These results are in the range of
353 observations made in the Tame River (UK; PE = 50%)³⁹ and Irwell and Mersey catchments
354 (UK; 35%)³⁴ but lower than those made in Swiss floodplains ($>88\%$)¹⁹.

355 This study provides an accurate inventory of the qualities and quantities of plastics trapped in
356 a dredging deposition site and discusses the possible role of external forcing on MaP and MP
357 distributions. These initial promising data open the way for other studies, including those on
358 the redistribution of this contamination in deposited sediments, the associations between
359 plastics and other sedimentary particles, the transfer and degradation of plastics during soil
360 placement, and matrix changes.

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363 **Author Contributions**

364 C.A and G.B. conceived the idea for this piece. M.C., C.A., and G.B. designed the research.
365 M.C. and N.B. conducted the data collection and analysis under the supervision of I.D.W.
366 M.C., C.A., I.D.W., D.D. and G.B. wrote the manuscript.

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379 **Supporting Information**

380 Method details on the study area, sediment collection, preparation of the samples prior to
381 analysis, contamination protection, FTIR spectroscopy, sediment particle size distribution
382 analysis and data analysis. Main features of the sampled sites (Table S1), mean and range of
383 plastic concentrations (Table S2), results (P-values) of the statistical analysis (Table S3),
384 plastics concentrations within European river sediment (Table S4), images of macroplastics
385 (Figure S1) and microplastic shapes (Figure S2), grain size distribution of sediment samples

386 (Figure S3), overall FTIR spectroscopy analysis results (Figure S4), and the relationships
387 between plastic concentrations (Figure S5)(PDF).

388 **Abbreviations**

389 MPs: microplastics; MaPs: macroplastics; FTIR: Fourier Transform InfraRed; PE:
390 polyethylene; PP: polypropylene; PS: polystyrene; PVC: polychlorure vinyl; PA: polyamide;
391 PES: polyester; POP: persistent organic pollutants; WWTP: wastewater treatment plant; ATR:
392 Attenuated Total Reflection; DTGS: Deuterated Triglycine Sulfate; MCT: Mercuric
393 Cadmium Telluride; SRH: Scheirer-Ray-Hare

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547 **Abstract Graphic:** For Table of Contents Only



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