Climate Adaptation Science Center and Land Change Science Program

Microplastic Particles in Dust-on-Snow, Upper Colorado River Basin, Colorado Rocky Mountains, 2013–16

Open-File Report 2022–1061

U.S. Department of the Interior
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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
micrometer (µm)	25400	inch (in.)

Datum

Vertical coordinate information is referenced to the World Geodetic System 1984 (WGS84).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

ALM	all-layers-merged deposits
DOS	dust-on-snow
MP	microplastic
SSA	snow-surface albedo
WY	water year
≤	less than or equal to
>	greater than

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By Richard L. Reynolds,[1] Harland L. Goldstein,[1] Raymond F. Kokaly,[1] and Jeff Derry[2]

Abstract

Atmospheric dust deposited to snow cover (dust-on-snow) diminishes snow-surface albedo (SSA) to result in early onset and accelerated rate of melting, effects that challenge management of downstream water resources. During ongoing investigations to identify the light-energy absorbing dust particles most responsible for diminished SSA in the Upper Colorado River Basin of the Colorado Rocky Mountains, we found microplastic particles, which are defined as those less than 5 millimeters in any dimension. In each of the 38 samples that represented the last remaining dust layer during melt seasons of 2013–16, microplastics were identified by size, shape, and color, and their relative amounts were visually estimated using stereomicroscopy. Considering the remote, high-elevation settings of the sample sites, the microplastic particles must have been deposited from the atmosphere. The possible role of microplastics for diminishing SSA of snow cover in the Upper Colorado River Basin may be linked to the solar-energy absorptive properties of polymers and is the subject of ongoing investigation.

Introduction

A large body of research has shown that airborne particulate matter deposited to snow cover (dust-on-snow [DOS]) advances the timing and accelerates the rate of snow melt in the Upper Colorado River Basin of the Colorado Rocky Mountains (fig. 1), thereby challenging water-resource management over much the southwestern United States reliant upon Colorado River water (Deems and others, 2013; Painter and others, 2010, 2012; Skiles and others, 2012, 2015; Udall and McCabe, 2013). Our ongoing investigations of Upper Colorado River Basin DOS focus on the types of particulate matter having high capacity to absorb solar radiation and thus contribute the most to accelerated melting (Reynolds and others, 2020). Thirty-eight samples from 14 high-elevation sites (fig. 1; table 1) under current examination represented the last remaining dust layers that formed during late spring into early summer of 2013–16. These layers (the all-layers-merged [ALM] deposits) contain layers of atmospheric dust deposited from discrete dust storms and lesser amounts of fugitive dust deposited in the intervals between the deposition of individual dust-storm layers (fig. 2). Here we report the presence of microplastics in Upper Colorado River Basin DOS, which must have been transported and deposited through the atmosphere, that suggests microplastics diminish snow-surface albedo of Upper Colorado River Basin snow cover related to their capacity to absorb solar radiation. Previous work has shown the capacity for polymers to absorb solar radiation, such as high-density polyethylene, which has characteristic absorption features at 1.73, 2.31, and 2.35 micrometers (µm) (Kokaly and others, 2017; https://crustal.usgs.gov/speclab/data/GIFplots/GIFplots_splib07a/plots_by_wavelength_region/range2_visible_to_swir/splib07a_Plastic_HDPE_GDS391_Blu-Grn_ASDFRa_AREF_range2_vis_to_swir.gif). The potential for radiative effects of microplastics in the atmosphere and cryosphere has been recently proposed, but many uncertainties remain (Evangeliou and others, 2020; Revell and others, 2021).

[1]U.S. Geological Survey

[2]Center for Snow and Avalanche Studies

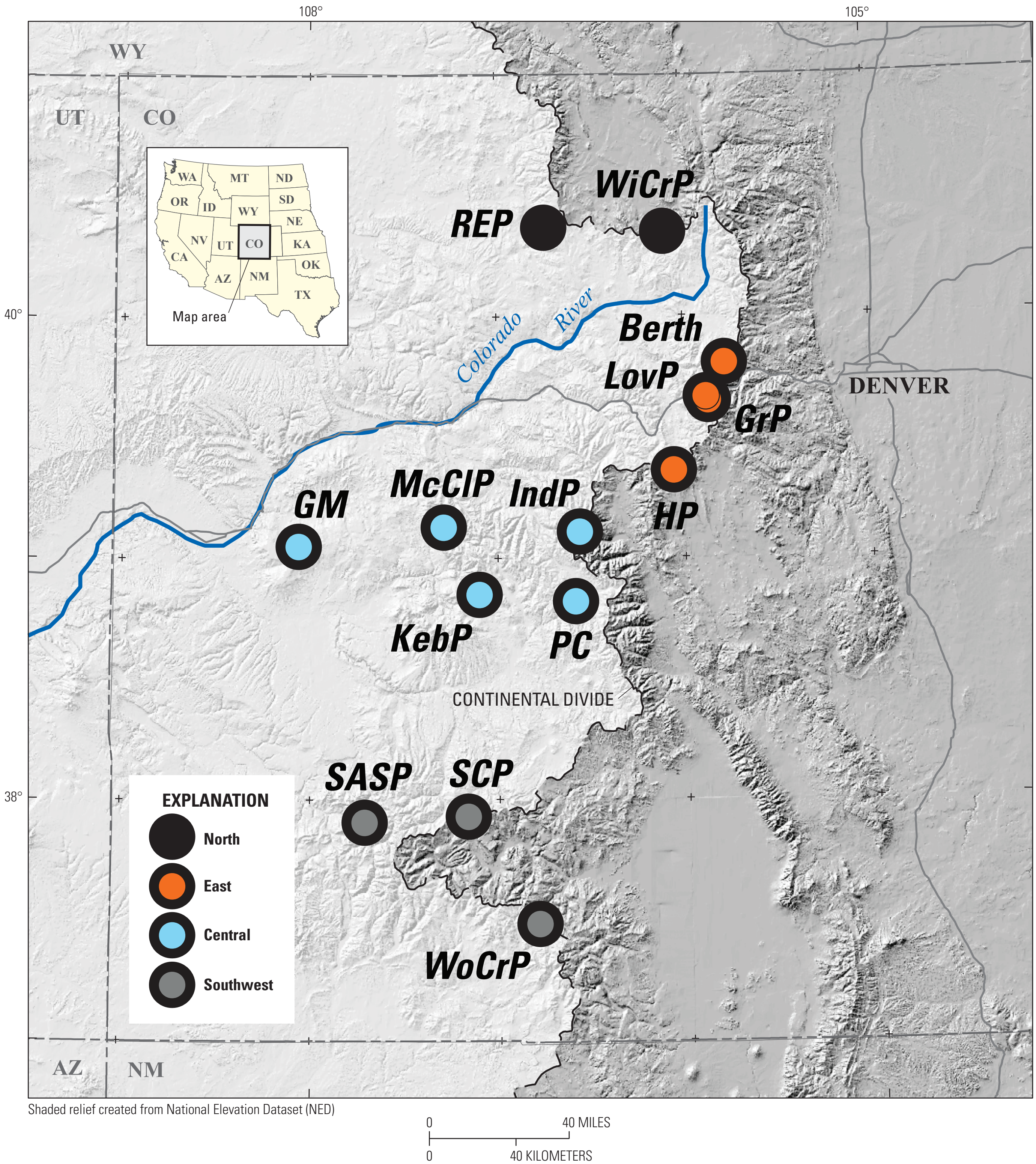

Figure 1. Map showing locations of sampling sites within the Upper Colorado River Basin, the Colorado River, and the Continental Divide (dashed line). Marker colors indicate groups by location: grey, southwest; cyan, central; red, east; black, north. Berth, Berthoud Pass; GM, Grand Mesa; GrP, Grizzly Peak; HP, Hoosier Pass; IndP, Independence Pass; KebP, Kebler Pass; LovP, Loveland Pass; McClP, McClure Pass; PC, Park Cone; REP, Rabbit Ears Pass; SASP, Swamp Angel Study Plot; SCP, Spring Creek Pass; WiCrP, Willow Creek Pass; WoCrP, Wolf Creek Pass; AZ, Arizona; NM, New Mexico; UT, Utah; CO, Colorado; WY, Wyoming.

Table 1. Locations and elevations of sampling sites in figure 1.

[Latitude and longitude are spatial coordinates in decimal degrees in WGS84 datum. Water year is defined as the period between 1 October of that year and 30 September of the next. Site elevation is in meters (m) above sea level. Location, four geographic groups shown in figure 1; WY, water year of collection (20xx)]

Site	Abbr	Latitude	Longitude	Elevation (m)	Location	WY
Berthoud Pass	Berth	39.8033	−105.7776	3,444	East	13–16
Grand Mesa	GM	39.0508	−108.0613	3,240	Central	13–16
Grizzly Peak	GrP	39.6471	−105.8689	3,383	East	13, 14, 16
Hoosier Pass	HP	39.3590	−106.0582	3,474	East	13, 14, 16
Independence Pass	IndP	39.1081	−106.5644	3,690	Central	14, 15
Kebler Pass	KebP	38.84976	−107.1003	3,058	Central	15
Loveland Pass	LovP	39.66337	−105.8791	3,658	East	15
McClure Pass	McClP	39.1294	−107.2885	2,896	Central	13, 14, 16
Park Cone	PC	38.8194	−106.5902	2,926	Central	13, 14, 16
Rabbit Ears Pass	REP	40.3683	−106.7388	2,865	North	13, 14
Swamp Angel Study Plot	SASP	37.9069	−107.7114	3,371	Southwest	13–16
Spring Creek Pass	SCP	37.9304	−107.1653	3,292	Southwest	13, 14, 16
Willow Creek Pass	WiCrP	40.3481	−106.0953	2,908	North	13, 14
Wolf Creek Pass	WoCrP	37.4838	−106.7955	3,336	Southwest	13–16

Figure 2. The dark snow surface of the all-layers-merged dust layer, contrasted with the white underlying snow, at the Swamp Angel Study Plot site. Photograph provided by the Center for Snow and Avalanche Studies.

Identification of Microplastics

Microplastics were identified using stereomicroscopy (at 100–700 ×) on the basis of their common characteristics of size, shape, and color as described in published accounts (for example, Allen and others, 2019; Bergmann and others, 2019; Brahney and others, 2020; Cowger and others, 2020; Dris and others, 2016; Evangeliou and others, 2020; Hidalgo-Ruz and others, 2012). The most common microplastics in the ALM-DOS samples were translucent filaments typically 10 µm in diameter and as much as one-half millimeter in length. Filaments of different colors—blue, red, green, and black—were also present. Additionally, we visually estimated relative amounts of microplastic on the basis of numbers of filaments and divided samples into three classes of abundance:

- class 1, microplastics uncommon;
- class 2, microplastics common; and
- class 3, microplastics abundant.

Assignment of abundance class was made under 100 × magnification having a 7.7 mm^2 field of view. At this scale, the numbers of assumed microplastic filaments were counted for the entire field of view. Counts less than or equal to (≤) 10 were classified as class 1 (uncommon), greater than (>) 10 but ≤30 classified as class 2 (common), and >30 classified as class 3 (abundant). Such estimates were made at least twice for each sample, blind to sample designation and year of collection. The three microplastic classes are illustrated and contrasted in figure 3.

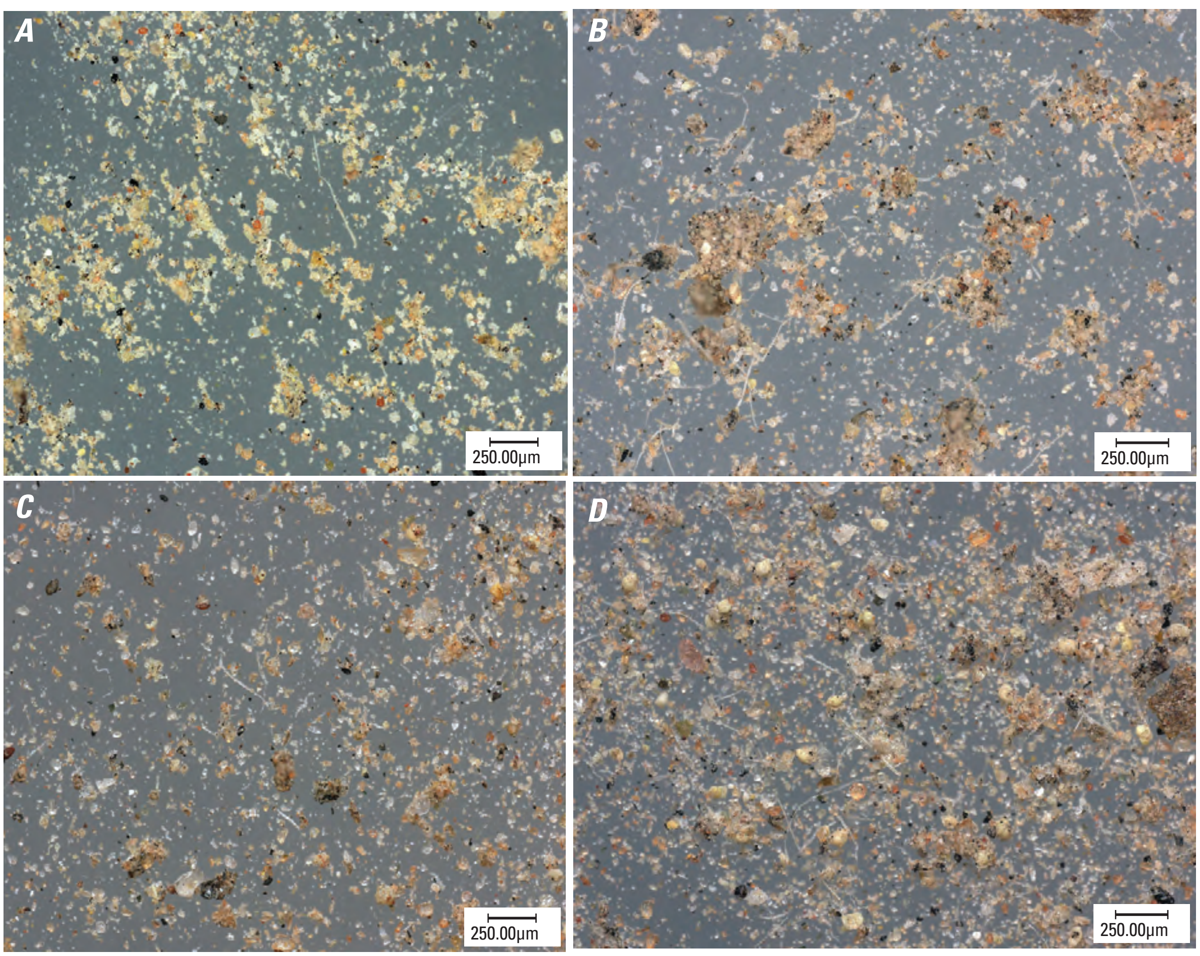

Figure 3. Photomicrographs of bulk sediment with microplastic (MP) particles (light-colored long, thin filaments) at 100 × magnification. In these samples, the amounts of the plastic filaments defined the MP classes. *A*, MP class 1, sample Swamp Angel Study Plot water year 2013 (WY13); *B*, MP class 3, sample Swamp Angel Study Plot WY15; *C*, MP class 2, sample Grand Mesa WY14; *D*, MP class 3 sample Grand Mesa WY16. Scale bar in lower right is 250 µm.

Is Microplastic Deposition Increasing in Upper Colorado River Basin DOS?

Examination of the 38 samples suggests that amounts of microplastics in the water year (WY) 2015 and WY 2016 samples were greater compared to microplastics in the WY 2013 and WY 2014 samples (fig. 4). The sample-site locations did not influence these amounts. Whether or not our observations indicate an increasing influence of microplastics on snow-surface albedo remains an open question.

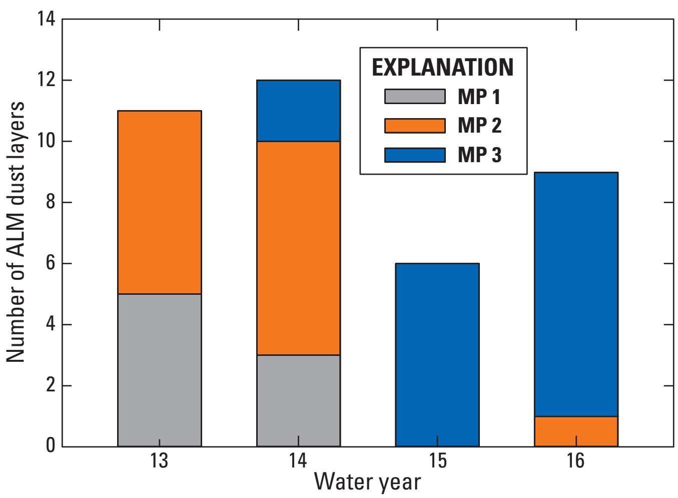

Figure 4. Microplastic abundance classes by water year for the all-layers-merged (ALM) dust layers. Microplastic (MP) classes: MP 1, class 1; MP 2, class 2; MP 3, class 3.

Regional and Global Context of Microplastics in Upper Colorado River Basin Snow

Our observations of atmospherically deposited microplastics in the Upper Colorado River Basin snow are unsurprising, even expected. Airborne microplastics have been found in many remote locations in the western United States (Brahney and others, 2020), and they have been described in numerous settings across most of the globe, including Arctic ice floes and alpine environments of the Pyrenées and the European Alps (Allen and others, 2019; Bergmann and others, 2019; Brahney and others, 2021; Evangeliou and others, 2020; Revell and others, 2021; Trainic and others, 2020). Recently, microplastics have been identified in human blood and lung tissue (Jenner and others, 2022; Leslie and others, 2022). The production and usages of plastics continue to increase (Borrelle and others, 2020), presaging higher volumes of plastic wastes in general and microplastics deposited from the atmosphere in particular (Revell and others, 2021). One goal of future research is to investigate possible linkage between increased plastic use and the amount of microplastics found in Upper Colorado River Basin DOS.

Additional environmental effects of microplastics, aside from their possible influence on the onset and rate of snow melt, warrant investigation. Firstly, microplastics in DOS are recognized pollutants that may provide clues to the origins and sources of other anthropogenic contaminants, such as metals and forms of carbonaceous matter produced by industrial and transportation activities. Secondly, microplastics may have deleterious effects on montane ecosystems, including soils, streams, and lakes (Ding and others, 2022; Li and others, 2020).

Summary

Layers of atmospheric dust deposited to snow cover in the Upper Colorado River Basin, Colorado Rocky Mountains, were examined for particulate matter that absorbs solar radiation causing advanced onset and accelerated timing of snow melt. Microplastic filaments and fragments were identified by size, shape, and color in 38 samples from the last remaining dust layer during melt seasons of 2013–16. Visual estimates of relative microplastic amounts under high magnification suggested more microplastic deposition during snow accumulation in 2015 and 2016 compared with amounts deposited during 2013 and 2014. Future work could examine subsequent dust-on-snow layers to determine interannual variation in microplastic amounts, test for trends in such amounts, and elucidate the possible role of microplastics for diminishing snow-surface albedo in the Upper Colorado River Basin using spectroscopic techniques.

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