The Laryngoscope

SYSTEMATIC REVIEW

Micro- and Nanoplastic Toxicity in Upper Respiratory Tract: A Scoping Review

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ABSTRACT

Objectives: To review the current literature findings dedicated to the toxicity of nano- and microplastics (NMPs) in the upper respiratory tract.

Data Sources: PubMED, Cochrane Library and Embase databases.

Review Methods: Three independent investigators conducted the literature search for the documentation and toxicity of NMP in the upper respiratory tract according to the PRISMA statements. Primary outcomes included NMP types, shape, density, sizes, the environment (air, mask wearing, plasticdevice), and the histological and physiological modifications associated with the deposit of NMP.

Results: The scoping review included 12 studies (10 clinical, 2 experimental) with 356 human subjects. NMPs were detected in all samples, predominantly as fragments (10–500 μm), except in mask-wearers where fibers predominated. Polypropylene, polycarbonate, and polyurethane were the most common. Clinical studies showed higher NMP density in patients with nasal disorders with an increased permeability of mucosa (rhinosinusitis and allergic rhinitis) than in healthy controls. Mask wearing and nasal lavage devices contributed to NMP deposition. Experimental studies demonstrated NMP cellular internalization with potential physiological disruption, including oxidative stress, autophagy dysfunction, and respiratory microbiome alterations. There was substantial heterogeneity across studies for NMP detection methods.

Conclusions: The current clinical and experimental studies demonstrate that both exposed and unexposed humans have nasal NMP detected in their nasal tissues and fluids. Mask wearing and the use of old plastic nasal lavage devices can contribute to this

Pr Lechien and Dr Albarajraji have similarly contributed to the study and can be joined as co-first authors. Pr Dubois and Pr Manto have similarly contributed to the study and can be joined as co-last authors.

deposition. While experimental studies suggest changes in tissue and cell physiology, the toxicity of NMP in nasal tissue remains poorly investigated and has not been conclusively demonstrated.

1 | Introduction

Since the 1960s, over 350 000 novel chemical compounds have been introduced into human environments through food, textile, and consumer product industries [1]. Among them, polymeric materials, emblematic of the Anthropocene, are important for functional objects, offering mechanical performance, lightness, and chemical resistance. Their development relied on petrochemical monomers and optimized several manufacturing processes. This model prioritized mass production over environmental concerns. Plastic pollution is now well-documented, with scientific attention for over 15 years [2]. Studies show that particle size—particularly micro—(< 2 mm) and nanoplastics (< 1 mm) (NMPs)—multiplies health impacts. These particles suspend in air, with high concentrations in metropolitan areas [3]. Emerging evidence indicated that airborne particles and inhalation of microplastic-contaminated air significantly increase the risk of respiratory, cardiovascular, and neurological disorders [3–7]. Within the respiratory tract, particles with an aerodynamic diameter < 100 μm primarily deposit into pulmonary epithelium through diffusion, sedimentation, and impaction mechanisms, and have been identified in sputum, nasal, laryngeal, and pulmonary tissue specimens [8–10]. While literature addressing the detection and toxicity of NMPs is growing across most medical disciplines, contributions from the otolaryngology field remain limited, with existing publications predominantly examining the biological and clinical toxicity of NMPs on sinonasal respiratory epithelium [10]. The investigation of NMP-related sinonasal epithelial findings is particularly significant because nasal epithelium may serve as a gateway of NMPs into the host organism through the nasal vascularization and the deposit of the smallest particles in the lower respiratory tract [11].

This paper aims to comprehensively review current literature regarding NMP deposition and potential toxicity in the field of rhinology.

2 | Methods

The criteria for publication inclusion and exclusion were based on the population, exposure, outcome (PEO) framework [12]. Three independent investigators (JRL, AM, MAB) conducted the literature search according to the PRISMA checklist for reviews, especially the PRISMA extension for scoping reviews [13, 14], and studies were reported as per PRISMA guidelines.

2.1 | Patient Population

Prospective, retrospective, controlled, uncontrolled, or randomized clinical studies published from January 2000 to March 2025 were considered if they included nasal data of adult patients exposed to varying amounts of plastic exposure. Studies were published in English peer-reviewed journals and reported data for more than 5 adults. Authors had to clearly specify the inclusion criteria considering the disease diagnosis or the exclusion criteria of presumed healthy individuals. There was no exclusion criteria based on ethnicity, socioeconomic status, comorbidities, and the types of NMPs. Animal and experimental investigations were considered.

2.2 | Exposure

The exposure consisted of NMP in everyday life or throughout a nasal irrigation regimen.

2.3 | Outcomes

The following general outcomes were collected for human clinical studies: study design, number of patients, materials, sex ratio, age (mean/median), and disease features. The primary outcomes included the types and concentrations/density of NMP, shape, sizes, the environment (air, mask wearing, plastic device), and the histological and physiological modifications associated with the deposit of NMP. Comparative studies comparing several groups for the NMP dose-effect, toxicity of NMP types, and other NMP findings were considered. For experimental studies, authors analyzed the in vitro or in vivo model features, NMP characteristics, the methods of toxicity evaluation, and results. The secondary outcomes included the substantial comorbidities and environment that could affect the outcome investigation (e.g., allergy, occupational factors, tobacco consumption, laryngopharyngeal reflux disease, and other respiratory comorbidities).

2.4 | Search Strategy

Three independent authors conducted the literature search using PubMed, Embase, and Cochrane Library databases. The databases were screened for abstracts and titles referring to the documentation of NMPs in sinonasal tissues of adults. The following keywords were associated with AND/OR in databases: ‘anoplastic’; ‘microplastic’; ‘nasall’; ‘nose’; ‘rhinology’; ‘epithelium’; ‘toxicity’; ‘respiratory’. The investigators analyzed the full texts of the selected publications. The results of the search strategy were reviewed for relevance, and the reference lists of the selected publications were examined for additional pertinent studies. Investigators extracted potential discrepancies, and synthesized data were discussed and resolved by the investigators.

3 | Results

Of the 63 retrieved papers, 12 met the inclusion criteria (Figure 1). There were 10 clinical studies (Table 1) [11, 15–23], including 4 prospective controlled [11, 16, 20, 22], 3 prospective uncontrolled [17, 21, 23], and 2 experimental cross-sectional [15, 18, 19]. The design of one study was either clinical or experimental with experimentations on tissues from clinical patients (Table 1) [16]. Three experimental studies were included

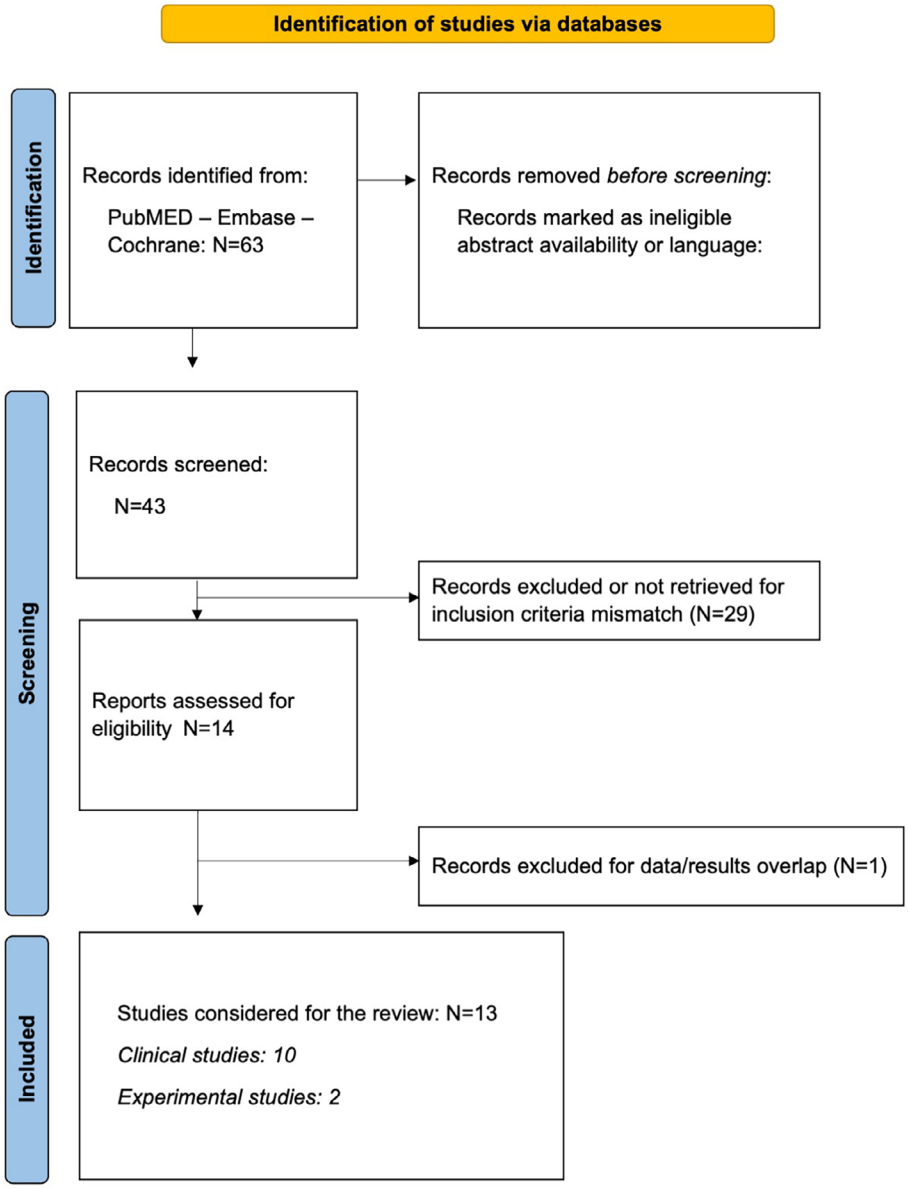

FIGURE 1 | PRISMA chart flow.

in the present review [24–26]. The demographics are available in Table 2. The clinical studies included 356 subjects with a mean age ranging from 18 to 64 years. There were 200 (56.2%) females and 146 (41.0%) males. Sex was not specified in 10 cases. All studies focused on the nasal compartment. There was no study investigating the deposit of NMPs in other upper respiratory regions, that is, larynx and pharynx.

3.1 | Clinical Investigation Findings

3.1.1 | Clinical Controlled Studies

Among the 4 prospective controlled studies [11, 16, 20, 22], Paplinska-Goryca et al. investigated the NMP-related tissue/cell toxicity and physiological changes in specimens from healthy individuals, asthma, and chronic obstructive pulmonary disease (COPD) patients [16]. Using several approaches, the authors demonstrated that NMP exposure led to a significant decrease in transepithelial electrical resistance in healthy individuals and COPD patients, an increase in pro-inflammatory cytokines in asthma subjects, and enhanced cell motility, chemokine signaling, leukocyte migration, and chemotaxis in COPD [16]. Tas et al. investigated NMP detection in patients with chronic rhinosinusitis without nasal polyps and in healthy individuals [20]. Using stereomicroscopy, the authors measured mean NMP densities of 3.9 particles/mL and 2.3 particles/mL in rhinosinusitis patients and healthy individuals, respectively, without detecting a significant correlation between nasal symptom severity and NMP density [20]. Tuna et al. reported similar observations in allergic rhinitis patients, who demonstrated significantly higher NMP density than healthy individuals [22]. Similarly to Tas et al., there was no significant association with nasal symptom severity (Score for Allergic Rhinitis). The influence of NMP air exposure was investigated by Zhang et al. in a comparative study of 20 high and 20 low NMP exposure individuals [11]. The authors detected 23–31 NMP types in nasal and gut samples, with mean sizes ranging from 20 to 500 μm [11]. Professional

TABLE 1 | Study features.

References	Study design	Subjects	F/M	Age	NMPs/materials	Outcomes	Results of Outcomes
Tuna (2025), Turkey (2015)	Cross-sectional	150 fluids	—	—	NP, Nasal fluid device	NMPs in different nasal irrigation options	Average 6.5 NMPs/product
	Experimental	95 products				NMPs exposure from single-use applications	Nasal wash bottles (41.2 particles/g)>
		No human					Syringe (0 particles)
Paplińska-Goryca, (2025), Poland (2016)	Clinical and	11 HC	6/5	39.5	PA	Cytotoxic effect (48-h exposure)	Not demonstrated
	Experimental	10 asthma	4/6	49.0		TEER changes (HC, COPD)	Decreased when exposed to NMPs
	Prospective	8 COPD	4/4	64.0		Inflammatory cytokine secretions (asthma)	Increased when NMP exposure
	Controlled					Cell motility, chemokine signaling, leukocyte	Increased when NMP exposure
						migration, and chemotaxis (COPD)	
Min (2024), South Korea (2017)	Prospective	10 SEP/ FESS	NP	NP	PE, PP, PS, PU, ACP, PES, Psco, Ppco, Nasal tissues	NMPs in nasal samples (NH, IT, MT, NF, MNCF)	86, 93, 51, 129, 31
	Uncontrolled					Types of NMPs and shape	Major types: PE, PES, PP, ACP—
							fragments (90.8%)-fibers (9.2%)
						Size of NMPs	Average size: 29.4 μm width, 57.1 μm length
Kim (2024), South Korea (2018)	Cross-sectional	6 fluids	—	—	PP, PE, PS, PET, Nasal fluid, device	Mean N of NMPs/ irrigation (300 mL)	CT = 33 < resued (1, 3, 6-month) = 68.7, 261.7, 204.3
	Experimental	6 reused				NMPs shape characteristics	Fragments/fibers:
		No human				(baseline, 1-, 3-, 6 month)	78/22%-86/14%-89/11%-87/13%
						NMPs polymer types (baseline, 1-, 3-, 6 month)	Predominantly PP>PE, PS, PET
						NMP size	Most: 20–50 μm > 10–20 μm

(Continues)

TABLE 1 | (Continued)

References	Study design	Subjects	F/M	Age	NMPs/materials	Outcomes	Results of Outcomes
Kim (2024), South Korea (2019)	Cross-sectional	6 fluids	—	—	PP, PE, PS, ABS, PMMA, Nasal fluid device	NMPs content in irrigation fluid bottles	New (5.9 NMPs/100 mL) = reused
	Experimental	No human					bottles (36.4 NMPs/100 mL)
						Fragments & fibers detected	Reused bottles (237 & 12) > CT (44 & 2)
						NMPs polymer types	PP>PE, PS, ABS, PMMA
Tas (2024), Turkey (2020)	Prospective	50 CRSNP	28/22	38.1	NP	NMPs density in nasal lavage fluid	Mean: 3.9–2.3 particles/mL
	Controlled	30 CT	15/15	33.6	Nasal tissue fluids	(Gr 1–2)	Gr1 > Gr2; NMPs detected in all samples
						Correlation NOSE and NMP density	NS
Zhang (2024), China (2021)	Prospective	113 students	69/44	> 18	PP, PE, PS, PET, Mask-exposed, nasal fluids	NMPs abundance in nasal lavage fluid (NE, SM, CM)	31.5, 41.2, 26.4 particles/g (NE>SM>CM)
	Uncontrolled					Influencing factors of high NMP density	Outdoor staying (> 2 h vs. 1 h); mask-wearing
						Mean NMP size (NE, SM, CM)	100–200 μm—< 100 μm—100–200 μm
						Fiber-shape %	88.3, 92.1, 90.1%
						NMP polymer composition (%)	NE = PC (58.7), PP (21.7)
							SM = PC (49.5), PA (44.4), CM = PC (54.3)
Tuna (2023), Turkey (2022)	Prospective	36 AR	24/12	33.7	NP, Nasal tissue, fluids	NMPs density in nasal lavage fluids (particles/mL)	*N* = 66/66; AR (3.1) > CT (2.4)
	Controlled	(SFAR > 6)				Correlation SFAR and NMP density	NS
		30 HC	14/16	35.3			

(Continues)

TABLE 1 | (Continued)

References	Study design	Subjects	F/M	Age	NMPs/materials	Outcomes	Results of Outcomes
Torres-Agullo (2023), Spain (2023)	Prospective	18 HC	12/6	NP	PA, EPDM, PE, PVDF, PS, PP, PVC, PES, Mask-exposed	NMPs in nasal lavage fluid	Mean 28.3 NMPs/5 mL—detected in all samples
	Uncontrolled					Effect of face mask type use	Surgical mask = cotton mask = natural exposure
						NMPs polymer types	PS (36%), PA (23%), EPDM (17%), PES (12%)
						NMPs size and shape	4. Fiber/fragments (53%–47%); 10–100 μm size range
Zhang (2022), China (2024)	Prospective	20 PFW	9/11	44.5*	31 types, PU, SR, EVA, PE	NMP types/size in air nasal samples (Gr1-2)	Gr1 = 23 types (20–500 μm), PU (38%), ACR (16%)
	Controlled	20 LEA	15/5	38.5*			Gr2 = 30 types, PU (50%), ACR (7%); Gr1 > Gr2
						NMPs in intestinal samples (Gr1-2%)	Gr1 = 31 types (20–500 μm); PU (37%); SR (13%)
							Gr2 = 31 types (20–500 μm); PU (29%), SR (7%)
							Gr1 > Gr2
						Influence of high NMP exposure in nasal and	+, increased bacteria associated with respiratory
						Intestinal microbiota composition	Disease, including Klebsiella and Helicobacter

Abbreviations: ABS, poly(acrylonitrile-butadiene-styrene) terpolymer; ACP, acrylic polymer; AR, allergic rhinitis; CM, cotton mask; COPD, chronic obstructive pulmonary disease; CRSNP, chronic rhinosinusitis without polyps; CT, healthy controls; EPDM, poly(ethylene-propylene-diene monomer); EVA, poly(ethylene-co-vinyl acetate) copolymer; IT, inferior turbinate; LDIR, laser direct infrared system; LEA, low-exposure area; MNCF, middle nasal cavity fluid; mo, month(s); MT, middle turbinate; NE, natural exposure; NF, nasopharyngeal fluid; NH, nasal hair; NP, not provided; NS, not significant; PA, polyamide; PC, polycarbonate; PE, polyethylene; PES, polyester; PET, polyethylene terephthalate; PFW, plastic factory workers; PMMA, polymethylmethacrylate; PP, polypropylene; PPco, Poly(propylene-co-ethylene) copolymer; PS, polystyrene; PSco, PS-based copolymer; PU, polyurethane; PVC, polyvinyl chloride; PVDF, polyvinylidene difluoride; SEP/FESS, septoplasty/functional endoscopic sinus surgery; SFAR, Score for Allergic Rhinitis; SM, surgical mask; SR, silicone resin; TEER, transepithelial electrical resistance.
*Median.

TABLE 2 | Demographics of clinical human studies.

Demographics (clinical studies)	*N* (%)
Healthy individuals	242 (68.0)
Chronic rhinosinusitis	50 (14.0)
Asthma	10 (2.8)
COPD	8 (2.2)
Operated patients (septoplasty/FESS)	10 (2.8)
Allergic rhinitis	36 (10.1)
Total	356 (100)
Sex	
Females	200 (56.2)
Males	146 (41.0)
Unspecified	10 (2.8)
Age (range of mean, years)	18–64

Abbreviations: COPD, chronic obstructive pulmonary disease; FESS, functional endoscopic sinus surgery; *N*, number.

NMP exposure significantly influenced the types and density of NMPs, with higher PU density in low versus high exposed individuals, and higher acrylic polymer density in high versus low exposed subjects [11]. Similar group differences were reported for gut samples (Table 1). Finally, the authors observed that NMP deposits were associated with increased abundance of certain intestinal bacteria commonly associated with respiratory disease [11].

3.1.2 | Uncontrolled Clinical Studies

Three uncontrolled studies investigated the following outcomes in human individuals: presence of NMPs in nasal tissue and secretions [17], and NMPs in nasal tissue exposed to several types of wearing masks [21, 23]. Min et al. collected nasal tissues from 10 patients who underwent septoplasty or functional endoscopic sinus surgery. The authors documented NMPs in all subjects and samples, with high NMP density in nasal fluids, inferior turbinate, and nasal hair samples. Consistent with other investigations, Min et al. reported that NMP shapes predominantly included fragments (90.8%) rather than fibers (9.2%) [17]. The association between NMP density and mask wearing was investigated in two clinical studies [13, 21]. In an 18-healthy-subject case series, Torres-Agullo et al. detected NMPs in all nasal fluid samples (mean = 28.3 particles/5 mL). The primary documented mask-related NMPs included polystyrene (36%), polyamide (23%), poly(ethylene-propylene-diene monomer) (17%), and polyester (12%), with a fiber/fragment balance of 53%–47% [23]. Zhang et al. recruited 113 students who performed nasal lavages after having worn surgical masks, cotton masks, or nothing [21]. Surgical mask wearing was associated with the highest NMP density, while cotton masks reported the lowest density. Naturally exposed students had intermediate mean density (Table 1). In this study, the authors reported that outdoor exposure time significantly influenced NMP density, with the highest values found in students who were outdoors for more than 2 h compared to those with 1 h of outdoor exposure. The mean size of NMPs matched with other studies, while the fiber-shape proportion was substantially higher (88.3%–92.1%) compared with other clinical studies [17, 19]. The NMP composition varied according to the type of mask, with lower polycarbonate proportion in mask-wearing groups compared to the natural exposure group (Table 1).

Clinical studies suggested that the density of NMPs is higher in patients with nasal diseases with an increased permeability of mucosa compared to healthy individuals. However, a causality relationship cannot be formally demonstrated.

3.2 | Nasal Device Studies

Three studies investigated the NMP deposit findings in nasal cavities through nasal lavage fluid devices [15, 18, 19]. Kim et al. used spectroscopy to investigate the NMP density in new and reused bottles used for nasal lavages [19]. They reported significantly higher NMP density in reused devices compared to new bottles, with a higher proportion of NMP fragments in samples. In this cross-sectional study, polypropylene was the most common type of deposited NMP [19]. In a longitudinal study, the same team confirmed that the use of reused nasal lavage devices was associated with a significantly higher proportion of NMP fragments compared to new devices [18]. In this study, the proportion of NMP fragments increased with the duration of device use, suggesting degradation of the plastic throughout use/time [18]. The concern regarding plastic devices for performing nasal lavages and the related risk of NMP deposit in tissues was similarly supported by Tuna et al., who showed that plastic bottles presented a higher risk of NMP deposit compared to syringes (Table 1) [15].

3.3 | Experimental Study Findings

Annangi et al. conducted a hazard assessment of polystyrene in primary human nasal epithelial cells in an in vitro experimental study [24]. The study evaluated cellular uptake using dye-labeled polystyrene nanoplastic particles visualized through confocal microscopy, confirming significant internalization by human nasal epithelial cells. Moreover, analysis examining cellular effects after NMP exposure (oxidative stress markers, mitochondrial function, and autophagy regulation) showed increased reactive oxygen species production, decreased mitochondrial membrane potential, and accumulation of autophagy markers (LC3-II and p62 proteins). This experimental study suggested that polystyrene disrupts normal cellular waste management processes, leading to defective autophagy mechanisms that could contribute to cellular dysfunction and potential tissue damage [24].

Zha et al. explored airborne NMP impact on the respiratory microbiome of mice. They showed that NMPs disrupted normal nasal bacterial communities, with microplastics more strongly affecting lung bacteria than nanoplastics [25]. Specific bacterial changes were identified: microplastic exposure increased

TABLE 3 | NMP detection and study outcomes.

Outcomes	*N*	References
Origins of measured NMPs		
Nasal lavage bottles	3	[15, 18, 19]
Nasal lavage syringes	2	[15, 18]
Air products	5	[11, 16, 17, 20, 21]
Wearing masks	2	[21, 23]
Methods (detection)		
Stereomicroscopy	3	[15, 20, 22]
Raman spectroscopy	3	[16, 18, 19]
μ-FTIR (Thermo microscopy)	2	[17, 23]
Polarized light microscopy (LDIR)	2	[11, 21]
NMP particle measurement and outcomes		
Number of NMP particles	3	[15, 17, 21]
Average number/irrigations (mL)	5	[18–20, 22, 23]
TEER changes (tissue resistance)	1	[16]
Inflammatory markers and cells	1	[16]
Clinical NMP-symptom severity correlation	2	[20, 22]
Cytotoxic effect of NMP	1	[16]
Types of NMPs	6	[11, 17–19, 21, 23]
Shape (fragment/fiber proportions)	5	[17–19, 21, 23]
Microbiome diversity and populations	1	[11]

Abbreviations: LDIR, laser direct infrared system; *N*, number; NMP, nano-micro-plastics; TEER, transepithelial electrical resistance.

nasal Staphylococcus and lung *Roseburia*, while nanoplastics increased nasal *Prevotella* and certain lung bacteria. Several bacterial species were identified as potential biomarkers for plastic-induced respiratory disruption.

3.4 | NMP Outcomes and Methodological Features

The material, NMP assessments, and outcomes are summarized in Tables 3 and 4. The origins of documented NMPs primarily consisted of air particles [11, 16, 17, 20, 21], while five studies specifically investigated the NMPs related to nasal lavage devices [15, 18, 19], and wearing masks [21, 23]. There was variability across studies for the NMP detection methods, with three studies using several types of spectroscopy [16, 18, 19], and three using stereomicroscopy (Table 3) [15, 20, 22]. Nine primary outcomes have been used in studies. The most common included absolute or mean (density) number of NMPs, types of NMPs, and shapes (Table 3).

The size, shape, and types of NMPs are presented according to the sample in Table 4. In most studies, the size of NMPs ranged from 10 to 500 μm. Fragments were predominantly found in most samples, except for subjects with surgical and cotton masks, where fibers were more common than fragments. The types of NMPs found in studies depended on the methods used to document NMPs. However, studies suggested that polypropylene, polycarbonate, and polyurethane were the most common NMPs found in samples (Table 4).

4 | Discussion

The literature dedicated to the MNP deposits and their related toxicity in human tissue is growing, with recent research demonstrating that MNPs can be involved in the development of cardiovascular, respiratory, and brain disorders [3–7]. The investigation of MNPs in the upper respiratory tract is important for exploring their roles in the development of sinonasal diseases and the potential mechanisms underlying their entry into the host through the upper aerodigestive tract mucosa (e.g., nasal-brain axis).

TABLE 4 | NMP features in samples.

Samples	*N*	References	Size	Shape (%)	Types (most prevalent)
				Fragment/fiber	
New nasal lavage devices	1	[15]	10–50 μm	78–96/4–22	PP, PE, PS, PET
Reused nasal lavage devices	1	[19]	NP	95/5	PP, PE, PS, ABS, PMMA
Nasal tissues and fluids	4	[11, 15, 20, 22]	20–200 μm	90.8/9.2	PE, PES, PP, ACP, PU, ACR
Respiratory tissue and cells	2	[16, 17]	NP	NP	NP
Nasal lavages of subjects with surgical mask	2	[21, 23]	10–200 μm	7.9/92.1	PC, PA, PS, EPDM, PES
Intestinal tissue samples	1	[11]	20–500 μm		PU, SR

Abbreviations: ABS, polyacrylonitrile-butadiene-styrene terpolymer; ACP, acrylic polymer; EPDM, poly(ethylene-propylene-diene monomer); EVA, poly(ethylene-co-vinyl acetate) copolymer; NP, not provided; PA, polyamide; PC, polycarbonate; PE, polyethylene; PES, polyester; PET, polyethylene terephthalate; PMMA, polymethylmethacrylate; PP, polypropylene; PS, polystyrene; PU, polyurethane; PVC, polyvinyl chloride; PVDF, polyvinylidene fluoride; SR, silicone resin.

The findings of the present review support that, depending on environmental factors (exposure to air), MNPs are commonly found in nasal tissues and fluids, particularly in subjects exposed to mask wearing or using certain nasal lavage devices; the latter being particularly prevalent in otolaryngology. Although the data available in the literature remain limited, the review of experimental studies supports that MNPs should be associated with potential physiological disruptions, including oxidative stress, autophagy dysfunction, and respiratory microbiome alterations [24, 25].

The impairment of airway epithelial barrier function by MNPs was supported in a recent mouse model of asthma where the co-exposure to allergens and polyethylene NMPs induced a higher degree of inflammatory cell infiltration, collagen deposition, allergen sensitization, hyperplasia of bronchial goblet cells, and Th2 immune bias than exposure to house dust mites alone [26]. In this study, Hu et al. reported an aggravation of oxidative stress injury in the lungs of the asthma model, which was associated with high production of some cytokines [26]. Other experimental studies supported NMP toxicity on respiratory mucosa [27, 28]. Wei et al. observed in a mouse model that polystyrene and dibutyl phthalate (i.e., a plasticizer commonly used in the plastics industry), which are both plastic pollution derivatives commonly found in the natural environment and identified in nasal mucosa and fluids, caused pathological changes in airway tissue through increased oxidative stress and inflammatory response, aggravating eosinophilic allergic asthma in asthma mice. The authors observed particularly NMP-related mitochondrial morphological changes and metabolomic alterations, which were not described in other investigations [27].

In this review, two studies reported that mask wearing is associated with the deposit of NMPs in nasal respiratory mucosa [21, 23] While the authors did not conduct additional mechanistic investigations linking nasal NMP deposits and mucosal inflammatory/injury processes, they suggested a potential toxicity of mask and textile microfibers, especially nylon and polyester microfibers, which may inhibit the development of airway organoids and the long-lasting epithelial cell development [28]. However, it is important to note that Zhang et al. included in their "natural exposure" group some students without mask wearing and others with mask wearing freely according to their usual lifestyle and behavior. This heterogeneity may limit the validity of this group for the comparison with other ones.

Although a growing literature in pulmonology, internal medicine, and neurology, the current literature in otolaryngology remains limited and focused on the nasal compartment. The present review highlights a substantial heterogeneity across studies for the methods of NMP detection, which is the primary limitation of the review. The method is particularly important in chemistry because there are several degrees of sensitivity for detecting and characterizing the NMPs in human tissues, fluids, and in some medical devices (nasal lavage bottle).

From a methodological standpoint, the NMP nanoscale size, varied shapes, and complex chemical composition make their analysis particularly challenging. Thus, the consideration of the following methodological points, which were not fully considered in the literature, is important for future studies.

After digestion in basic medium or separation such as field flow fractionation or hydrodynamic chromatography, the most common techniques used to highlight the isolated NMP can be optical or fluorescence microscopy and flow cytometry [29, 30]. Dynamic light scattering allows the measurement of the particle size distribution, the average hydrodynamic size, and the polydispersity of the nanoparticles. Nanoparticle tracking analysis has been developed to determine the concentrations of samples. This technique has the advantage of providing individual particles intensity and motion videos [31, 32].

Spectroscopic techniques are commonly used to determine the chemical composition and physical characteristics of NMPs. Among them, Raman spectroscopy offers high-resolution, non-destructive analysis with minimal sample preparation. It excels at identifying polymer types through their vibrational signatures, even at sub-micron scales [30, 33]; Fourier transform infrared spectroscopy (FTIR) helps identify organic materials, while micro-FTIR (μ-FTIR) can determine size, shape, and polymer type in small particles [33].

Near-infrared spectroscopy is useful for quick screening; although it is less precise than Raman or FTIR for detailed polymer analysis [29, 34]. X-ray fluorescence and X-ray photoelectron spectroscopy provide elemental composition data, particularly valuable for detecting metal additives in plastics [30].

Microscopy combined with spectroscopy delivers physical and chemical insights: it visualizes particle morphology but requires spectroscopic tools for chemical identification [32]. Confocal Raman imaging creates hyperspectral maps merging spatial and chemical data, which is ideal for locating NMPs in biological tissues [30, 35]; while fluorescence microscopy effectively tracks tagged microplastics in biological samples [35].

Mass spectrometry techniques detect polymer types and additives at low concentrations. Py-GC–MS identifies polymers via thermal degradation products [36], offering quantification but lacking size information. ICP-MS measures metal content in NMPs for toxicity evaluations [29]. MALDI suits imaging characterization, while TOF and orbitrap spectrometry are appropriate for polymer analysis [37].

Despite advances, the lack of standardized protocols, the difficulties in detecting sub-1 μm particles, and background noise in complex biological media are several challenges for future studies. Moreover, despite some promising studies linking microbiome alteration related to NMPs, there is no reliable technique to assess microbial activity on NMP surfaces, hampering understanding of their role as biological nanovectors. At this emerging time, these methodological points are important for conducting future studies investigating the potential of NMPs in the development of ear, nose, and throat inflammatory disorders or neoplasia.

5 | Conclusion

The human health risks posed by NMP deposits in tissue are emerging in many medical specialties, plastic pollution being a major pressing challenge for health at a global scale.

In otolaryngology, evidence shows that NMPs are present in human nasal tissues, with mask wearing and plastic nasal lavage potentially increasing deposits. Especially, NMP nasal lavage devices appear to be a source of NMP exposure to patients and that old nasal lavage devices appear to increase that exposure. Patients need to be informed about the risk of using old devices. While experimental studies suggest physiological changes in tissues and cells, nasal tissue toxicity remains insufficiently investigated. The investigation of nasal NMP deposit and host entry is important because NMPs can access the brain via the bloodstream (crossing the blood–brain barrier) and the olfactory pathway, which is associated with several neurological disorders. Given widespread NMP exposure and emerging health implications, standardized detection methods and comprehensive studies accounting for environmental and clinical factors are urgently needed.

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The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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