Original article

Are Polymer-Based Single-Use Face Masks Subject to Biofouling in Seawater?

A. V. Bondarenko *, L. I. Ryabushko, A. A. Blaginina

A. O. Kovalevsky Institute of Biology of the Southern Seas of RAS, Sevastopol, Russia

* *e-mail*: *gonzurassa@mail.ru*

Abstract

The paper presents for the first time the results of an experimental study of the species composition and quantitative characteristics: species richness (S), abundance (N) and biomass (B) of the microalgae and cyanobacteria in the fouling of synthetic single-use face masks as a technogenic substrate. Fouling experiments were conducted for two months and for one year in 2021–2022 in Karantinnaya Bay (the Black Sea). The surface of masks and microfouling suspensions were studied using light and electron microscopy. In total, 48 taxa from 5 phyla were noted: Cyanoprocaryota – 3 species, Bacillariophyta – 36, Dinophyta – 6, Haptophyta – 2, Ochrophyta – 1. After a two-month exposure of masks, 30 species were found, and 40 species were found after a one-year exposure, 22 species were shared. For the first time for the bay, we have identified benthic species of diatoms *Cocconeis guttata* and *Karayevia amoena*. Out of 14 benthic typical colonial fouling species of diatoms, *Tabularia fasciculata* was on all masks with 100 % occurrence. Solitary-living species were also recorded among the frequently encountered ones: potentially toxic *Halamphora coffeiformis* and bentoplanktonic *Cylindrotheca closterium*. The features of the mask fouling at different exposure periods in the sea are the absence of the formation of diatoms colonies, unlike fouling on other anthropogenic and natural substrates, and low quantitative characteristics at different periods: after a two-month exposure, the corresponding values were: S – 10–15 species, N – 9200–13100 cells/cm^2, and B – 0.001–0.02 mg/cm^2; after a one-year exposure, the same were: S – 8–14 species, N – 4900–8400 cells/cm^2, B – 0.01–0.03 mg/cm^2.

Keywords: diatoms, cyanobacteria, microalgae, fouling, single-use face masks, Crimea, coastal waters, Black Sea

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Подвержены ли биообрастанию синтетические медицинские маски в морской воде?

А. В. Бондаренко *, Л. И. Рябушко, А. А. Благинина

Институт биологии южных морей им. А. О. Ковалевского РАН, Севастополь, Россия
* *e-mail: gonzurassa@mail.ru*

Аннотация
Впервые представлены результаты экспериментального изучения видового состава и количественных характеристик (обилие видов, численность и биомасса) микроводорослей и цианобактерий в обрастании синтетических медицинских масок в качестве техногенного субстрата. В 2021–2022 гг. в б. Карантинной (Черное море) были проведены эксперименты по обрастанию в течение двух месяцев и одного года. Поверхность масок и суспензии микрообрастаний изучали с использованием световой и электронной микроскопии. Всего обнаружено 48 таксонов из 5 отделов: Cyanoprocaryota – 3 вида, Bacillariophyta – 36 видов, Dinophyta – 6 видов, Haptophyta – 2 вида, Ochrophyta – 1 вид. При двухмесячной экспозиции масок найдено 30 видов, при годичной – 40, при этом 22 вида были общими. Впервые для бухты нами указаны бентосные виды диатомовых водорослей *Cocconeis guttata* и *Karayevia amoena*. Из 14 пеннатных типичных колониальных видов-обрастателей диатомовых водорослей на всех масках со 100 %-ной встречаемостью отмечен вид *Tabularia fasciculata*, среди одиночноживущих видов часто отмечались потенциально токсичный *Halamphora coffeiformis* и бентопланктонный *Cylindrotheca closterium*. Особенностью обрастания является отсутствие образования колоний диатомовых водорослей, в отличие от обрастания на других антропогенных и природных субстратах, и низкие количественные показатели при разных сроках экспозиции – при двухмесячной соответствующие значения составляли: обилие видов – 10–15 видов, численность – 9200–13 100 кл./см^2 и биомасса – 0.001–0.02 мг/см^2; при годичной – обилие видов – 8–14 видов, численность – 4900–8400 кл./см^2, биомасса – 0.01–0.03 мг/см^2.

Ключевые слова: диатомовые водоросли, цианобактерии, микроводоросли, обрастание, синтетические медицинские маски, крымское прибрежье, Черное море

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Introduction

The plastisphere of the World Ocean contains 8–12 million tons of waste, and in recent years, due to the COVID-19 pandemic that has covered the entire world, single-use three-layer face masks have been added to the variety of anthropogenic debris entering marine ecosystems and accumulating there. Based on the annual estimate of global production of 52 billion masks, researchers estimate that 1.56 billion masks entered the World Ocean in 2020 (Fig. 1), representing between 4680 and 6240 tons of plastic pollution [1].

Like any other type of solid human-made waste entering marine ecosystems, face masks are an additional anthropogenic substrate for colonization by various organisms, mainly micro- and meiobenthic forms. The most studied substrates atypical for the natural habitat of hydrobionts in the sea include substrates of anthropogenic origin (glass, wood, plastic, synthetic polymer-based materials, etc.), which are populated mainly by bacteria, diatoms and cyanobacteria [1)] and participate in the transformation of the substrate and its partial utilization in the sea in different ways [2–12].

It has also been noted that bacteria, fungi, cyanobacteria and mainly diatoms create persistent biofilms on plastic and glass materials, subsequently competing for the substrate [1)] with invertebrates and macrophytes [5, 13].

As a substrate, a three-layer face mask represents a set of polymer-based fibers that form a textile fabric. Such masks are made from various non-woven materials, most often spunbond, mainly spunbond polypropylene. Spunbond is a microporous material that is resistant to aggressive environments and water, as well as to high and low temperatures. It has high strength, does not rot or mold. It is indicated that in the environment this material does not have any ability to form toxic compounds, and this determines its environmental safety [14].

Fig. 1. Used polymer-based single-use face masks washed up on the coast (URL: https://oceansasia.org)

However, the polymer-based material of single-use face masks determines the process of their long-term degradation under natural conditions in the sea.

[1)] Balycheva, D.S., 2014. [*Species Composition and Structural and Functional Characteristics of Periphyton Microalgae of Anthropogenic Substrates in the Crimean Coastal Part of the Black Sea.* Extended Abstract of Doctoral Dissertation]. Sevastopol, 24 p. (in Russian).

In this case, the destruction of synthetic fabric occurs almost immediately after entering the aquatic environment and is accompanied by the gradual release of microscopic polypropylene fibers that are capable of absorbing organic and inorganic pollutants, which leads to the toxicity of microplastics [12]. Consequently, masks have become a potential source of microplastic pollution of marine ecosystems with a known negative impact on various communities of aquatic organisms – from microforms of animals and plants to the largest representatives of the living world [12, 15–18].

It should also be taken into account that the polypropylene density (0.91 g/cm^3) is less than the water density (0.99 g/cm^3), and the outer layer of face masks is waterproof, so such personal protective equipment can move for a long time by currents in the water column of seas and oceans. Species that have colonized the surface of this substrate in one area can be transported over significant distances and become invasive in new water areas. In addition, biofilms formed in the water column on artificial polymer substrates can lead to the loss of buoyancy of these materials and their subsequent burial in bottom sediments, i. e., transition from one biotope to another. All this indicates the global scale of the problem of marine plastic pollution and the relevance of studying physico-chemical and biological processes in the plastisphere. The Black Sea is an inland body of water, which makes it very difficult to protect its biota from pollution, especially from plastic waste.

In connection with the above stated and also due to the lack of data in the literature concerning the biodegradation of face masks that run into the sea, the question comes up whether these synthetic materials are colonized at all and whether the processes of their biodestruction occur under the influence of microalgae and cyanobacteria at different exposure periods in the sea.

The purpose of this article is an experimental study of the species composition and quantitative characteristics of microalgae and cyanobacteria in the fouling of polymer-based single-use face masks at different exposure periods in Karantinnaya Bay (the Black Sea).

Materials and methods

To study the species composition, number, and biomass of the microalgae and cyanobacteria fouling single-use face masks in the sea, as well as to visually assess the integrity of the synthetic material after different periods of stay in sea water, the following experiment was carried out. A vertical collector, which consists of perforated plastic containers fixed on a rope with a buoy and an anchor with masks attached to them, was mounted in the area of a mussel and oyster farm in Karantinnaya Bay (44°61′83″ N, 33°50′34″ E) (Crimean coastal waters of the Black Sea). Holes in the walls of the containers provided constant access of sea water with micro- and meioorganisms living in it. The location depth of the containers was 3 m. At the same depth, a hermetically sealed cylinder with masks was fixed in sterile sea water. Accordingly, such masks were not exposed to the biotic factor while maintaining the influence of a number of abiotic factors, such as temperature, salinity, illumination, hydrodynamics, etc.

Some of the experimental masks were taken out two months (from 05.10.2021 to 10.12.2021) and a year (from 05.10.2021 to 09.11.2022) after their immersion in the sea. The masks remaining on the collector are the subject of subsequent study of fouling processes and observation of the polymer-based material degradation with longer exposure.

During the two-month exposure of the material, the water temperature varied within the range of 12.8–19.6 °C, and the salinity made 17.84–18.07 PSU. During the one-year exposure, the water temperature had positive values with its minimum in February 2022 (8 °C) and maximum in August (26.1 °C), and water salinity varied within the range of 17.84–18.52 PSU.

In the laboratory, the masks were cleaned of fouling. The study of the qualitative and quantitative characteristics of microalgae and cyanobacteria on the surfaces of the masks and in the resulting suspensions was carried out in light microscopes (LM) such as *Olympus CX*31 and *Axioskop* 40 (*C. Zeiss*) at a magnification of 10 × 20, 10 × 40, and 10 × 100. For a detailed study of cell morphology and identification of the species of diatoms, sample preparation was carried out for examination in a scanning electron microscope (SEM) *Hitachi SU*3500. Samples were prepared in two ways. In the first case, fibers and pores on the surface of single-use face masks were studied without treating the material with acids. At five points on the mask fabric, squares measuring 0.5 × 0.5 cm were randomly selected and cut out, left to dry completely in air, and then a thin layer of gold – palladium was sprayed on. The second case was to treat the resulting suspensions with acids according to the methods [19, 20] to clean the shells of diatoms and obtain their photographs, which was necessary for species identification.

Determination of the species composition of microalgae and cyanobacteria was carried out using monograph [21] and a number of papers [2), 3), 4), 5), 6)]. Names are given according to the algae database [7)]. The species richness (*S*), abundance (*N*), and biomass (*B*) of living microalgae cells were taken into account in a Goryaev chamber (hemocytometer) with a volume of 0.9 mm^3 according to the formulas of V.I. Ryabushko [22]. The species richness was determined as the number of species found in the counting chamber when viewing samples from each specific sample of experimental material.

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2) Guslyakov, N.E., Zakordonets, O.A. and Gerasimyuk, V.P., 1992. [*Atlas of Benthic Diatoms of the Nortwestern Black Sea and Adjecent Waterbodies*]. Kiev: Naukova Dumka, 112 p. (in Russian).

3) Konovalova, G.V., 1998. [*Dinoflagellates of Far East Seas of Russia and Adjacent Water Areas of the Pacific Ocean*]. Vladivostok: Dalnauka, 298 p. (in Russian).

4) Komárek, J. and Anagnostidis, K., 1999. *Cyanoprokaryota. 1 Teil: Chroococcales. Süßwasserflora von Mitteleuropa.* Bd 19/1. Heidelberg, Berlin: Spektrum Akademischer Verlag, 523 p.

5) Witkowski, A., Lange-Bertalot, H. and Metzeltin, D., 2000. *Diatom Flora of Marine Coast. Part I. Iconographia Diatomologica*. A.R.G. Gantner. Vol. 7, 925 p.

6) Ryabushko, L.I. and Begun, A.A., 2016. [D*iatoms of Microphytobenthos of the Sea of Japan (Synopsis and Atlas)*]. In two volumes. Sevastopol: PK “KIA”.Vol. 2, 324 p. (in Russian).

7) Guiry, M.D. and Guiry, G.M. 2023. *AlgaeBase*. National University of Ireland, Galway. [online] Available at: https://www.algaebase.org [Accessed: 31 August 2023].

Results and discussion

LM and SEM-based visual analysis of surface samples of face masks over the exposure period of two months and one year in Karantinnaya Bay near the mussel and oyster farm showed that all layers of three-layer masks were saturated with detritus, silt and sand fractions, juvenile barnacles, fragments of mollusk shells, etc. (Fig. 2). Particularly pronounced sediment was observed on masks after a one-year exposure, on which a larger amount of detritus was noted (Fig. 2, *b*).

A study of the outer and inner layers of single-use face masks after a two-month exposure showed that there were no attached microalgae cells or their colonies on the fibers and in the pores of the polymer-based material (Fig. 3, *a*, *b*). The species observed in our experiment were found separately; they lay freely on the canvas (Fig. 3, *c*) or among the fibers.

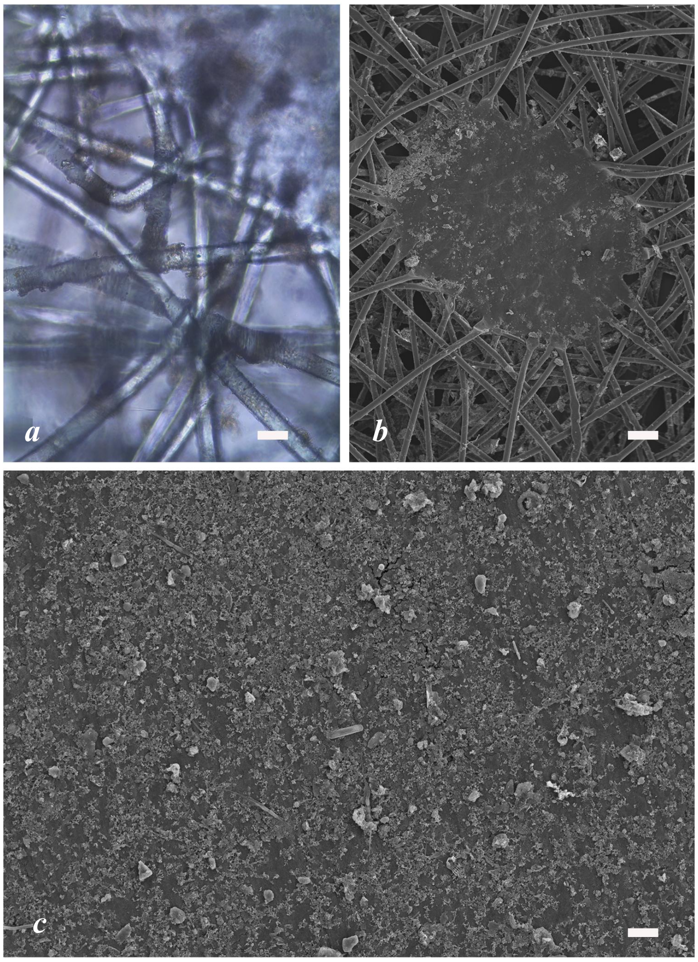
Meanwhile, many authors note that during the formation of biofilms on the surface of various artificial substrates, some species of diatoms *Cocconeis*, *Amphora*, *Achnanthes*, *Mastogloia*, *Karayevia*, etc. are capable of attaching directly to the polymer-based material [6, 11, 23]. The ability of individual diatoms to modify the structure of the substrate due to dense attachment to its surface or even penetration into it is also indicated [23, 24].

In total, 48 species of microorganisms belonging to 5 phyla: Cyanoprocaryota – 3, Dinophyta – 6, Haptophyta – 2, Ochrophyta – 1, Bacillariophyta (the most diverse) – 36 species and IST belonging to 28 genera (see Table) were noted in the fouling of masks at different exposure periods.

Analysis of the species structure of diatoms shows that Bacillariohyceae (9 orders, 16 families, and 21 genera) is the basic class of their diversity, which is typical for the microphytobenthos of the Black Sea.

Fouling of masks after a two-month exposure is represented by 30 species, including 3 species of cyanobacteria and 27 species of microalgae, of which 20 belong to phylum Bacillariophyta, 4 – to Dinophyta, 2 – to Haptophyta, 1 – to Ochrophyta (Table).

F i g . 2 . Light microscope (LM): meiobenthic fouling of the surface of face masks after a two-month (*a*) and one-year (*b*) exposure to the sea



F i g . 3 . The inner layer of a face mask of a two-month exposure: LM – polypropylene fibers (*a*), scanning electron microscope (SEM) – fiber pores (*b*); surface of the inner layer (*c*). Scale bar: 1000 µm (*a*), 100 µm (*b*), 10 µm (*c*)

The fouling of masks after a one-year underwater exposure amounted to 40 species and IST, of which 1 species each belongs to phyla Cyanoprocaryota and Ochrophyta, 32 – to Bacillariophyta, 4 – to Dinophyta, 2 – to Haptophyta (see Table). At different exposure times, 22 species were shared on the surface of the masks. For the first time for Karantinnaya Bay, we have identified benthic species of diatoms *Cocconeis guttata* and *Karayevia amoena*.

Most of the stated fouling microalgae are typical inhabitants of sea benthos, whose life activity is closely related to different types of substrates. The share of benthic species accounts for 67 %, planktonic species – 20 %, benthic-planktonic

The occurrence of microalgae and cyanobacteria species in the fouling of single-use face masks for 2021–2022 at different exposure periods in Karantinnaya Bay (Crimea, the Black Sea)

Taxon	Exposure period	
	Two months	One year
Bacillariophyta phylum		
Achnanthes brevipes C. Agardh 1824 *	+	+
Amphora ovalis (Kützing) Kützing 1844 *	+	+
A. pediculus (Kützing) Grunow 1875 *	+	+
Ardissonea crystallina (C. Agardh) Grunow 1880 *	+	+
Caloneis liber (W. Smith) Cleve 1894 *	–	+
Cerataulina pelagica (Cleve) Hendey 1937 **	+	–
Cocconeis guttata Hustedt et Aleem 1951 *	–	+
C. placentula Ehrenberg 1838 *	–	+
C. scutellum Ehrenberg 1838 *	–	+
Coscinodiscus sp. **	+	+
Cylindrotheca closterium (Ehrenberg) Reimann et Lewin 1964 ***	+	+
Grammatophora marina (Lyngbye) Kützing 1844 *	+	+
Diploneis bombus (Ehrenberg) Ehrenberg 1853 *	–	+
D. smithii (Brébisson) Cleve 1894 *	+	+
Halamphora coffeiformis (C. Agardh) Levkov 2009 *	+	+
Haslea subagnita (Proschkina-Lavrenko) Makarova et Karayeva 1985 *	+	–
Karayevia amoena (Hustedt) Bukhtiyarova 1999 *	–	+
Licmophora abbreviata C. Agardh 1831 *	–	+
Lyrella abrupta (W. Gregory) D.G. Mann 1990 *	–	+
Navicula ammophila var. *intermedia* Grunow 1882 *	+	+
Neosynedra provincialis (Grunow) D.M. Williams et Round 1986 *	–	+
Nitzschia lanceolata var. *minor* (Grunow) H. Peragallo et M. Peragallo 1900 *	–	+
N. sigma (Kützing) W. Smith 1853 *	–	+
Odontella aurita (Lyngbye) C. Agardh 1832 ***	–	+
Paralia sulcata (Ehrenberg) Cleve 1873 ***	+	–
Parlibellus delognei (Van Heurck) E.J. Cox 1988 *	+	+
Rhabdonema arcuatum (Lyngbye) Kützing 1844 *	–	+
Tabularia fasciculata (C. Agardh) Williams et Round 1986 *	+	+

Continued

Taxon	Exposure period	
	Two months	One year
T. parva (Kützing) D.M. Williams et Round 1986 *	+	+
Toxarium undulatum Bailey 1854 *	–	+
Trachyneis aspera (Ehrenberg) Cleve 1894 *	–	+
Tryblionella coarctata (Grunow) D.G. Mann 1990 *	–	+
T. hungarica (Grunow) Frenguelli 1942 *	+	–
T. punctata W. Smith 1853 *	+	+
Thalassionema nitzschioides (Grunow) Mereschkowsky 1902 ***	+	+
Thalassiosira sp. **	+	+
Dinophyta phylum		
Amphidinium sp. **	+	+
Prorocentrum compressum (Bailey) Abé ex Dodge 1975 ***	+	–
P. cordatum (Ostenfeld) J.D. Dodge 1976 ***	–	+
P. lima (Ehrenberg) F. Stein 1878 *	–	+
P. scutellum Schröder 1900 **	+	+
Protoperidinium brevipes (Paulsen) Balech 1974 **	+	–
Haptophyta phylum		
Anacanthoica acanthos (Schiller) Deflandre 1952 **	+	+
Emiliania huxleyi (Lohmann) W.W. Hay et H. Mohler 1967 **	+	+
Ochrophyta phylum		
Octactis speculum (Ehrenberg) F.H. Chang, J.M. Grieve et J.E. Sutherland 2017 **	+	+
Cyanoprocaryota/Cyanobacteria phylum		
Microcystis wesenbergii (Komárek) Komárek ex Komárek 2006 *	+	+
Pseudanabaena minima (G.S. An) Anagnostidis 2001 **	+	–
Spirulina tenuissima Kützing 1836 **	+	–
Total taxa:	30	40

* benthic species; ** planktonic species; *** benthic-planktonic species.

species – 13 % (Table). This ratio is close to the ratio on other artificial and natural substrates, which is described in the research work [1)] and in [4, 8, 9]. Diatom genera *Cocconeis* and *Tryblionella*, which include three species each, are characterized by the greatest diversity. The other ones are represented by one or two species (Table). Dinoflagellates of genus *Prorocentrum* (4 species) during two-month and one-year exposures were presented by two and three species, respectively. These algae, like diatom *Halamphora coffeiformis*, are potentially toxic species for biota and human [25].

Typical colonial benthic fouling species were found on the surface of the masks. They are *Tabularia fasciculata, T. parva, Grammatophora marina, Achnanthes brevipes, Ardissonea crystallina, Parlibellus delognei*, with benthic-planktonic species *Thalassionema nitzschioides*. Colonial species *Toxarium undulatum, Odontella aurita*, *Licmophora abbreviata, Rhabdonema arcuatum* were found only after a one-year exposure, while planktonic *Cerataulina pelagica* and bentic-planktonic *Paralia sulcata* were found only after a two-month exposure. Some species of diatoms are shown in SEM images: *Cocconeis placentula* (*a*), *C. guttata* (*b*), *Th. nitzschioides* (*c*), *C. closterium* (*d*), *A. brevipes* (*e*), *A. pediculus* (*f*), *Karayevia amoena* (*g*), *Halamphora coffeiformis* (*h*) (Fig. 4).

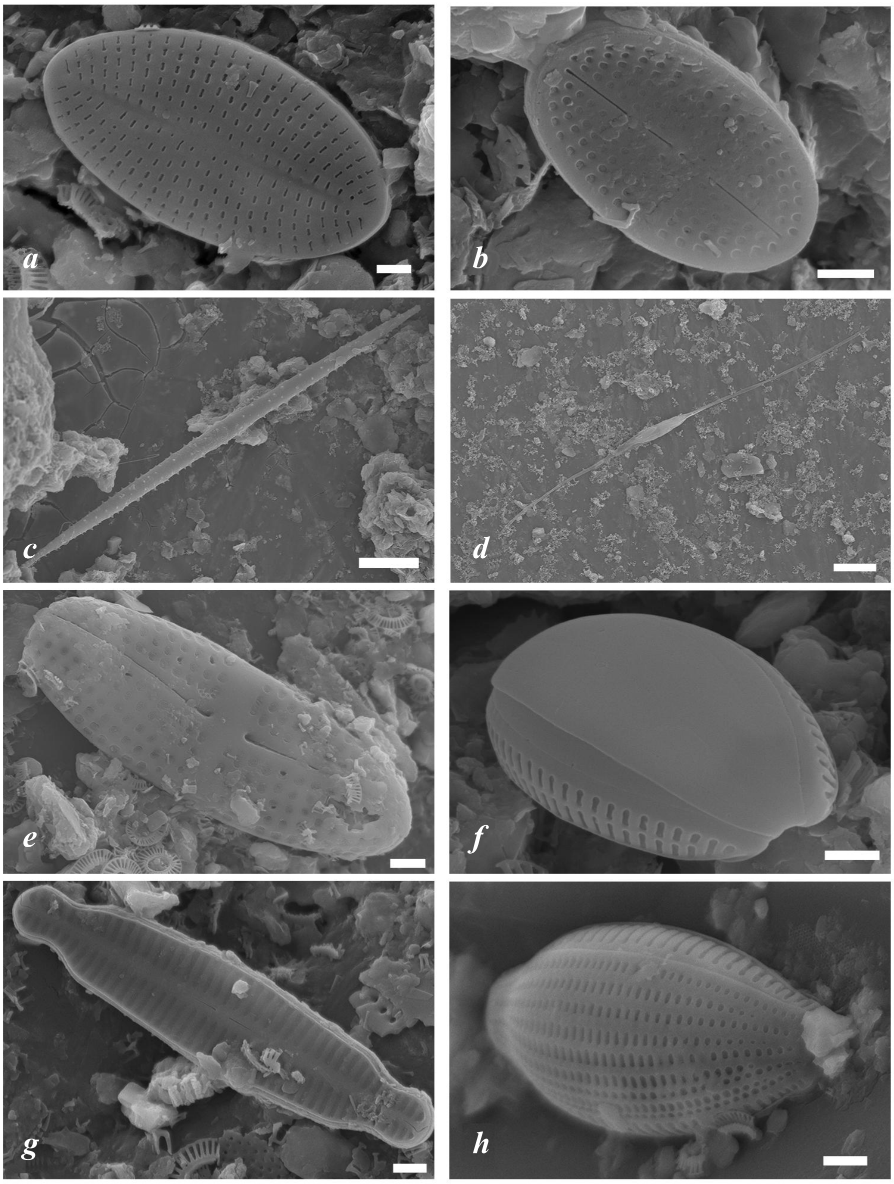
Cosmopolitan species *T. fasciculata* showed the maximum occurrence (100 %). Other species *A. pediculus*, *C. closterium*, *Gr. marina*, *H. coffeiformis*, *Tabularia parva*, *Thalassiosira* sp., dinophyte *Prorocentrum scutellum*, and haptophyte *Emiliania huxleyi* made 67 %, other species – from 17 % to 50 %.

It should be noted that, in comparison with other artificial substrates that we studied earlier, single-use face masks with two-month and one-year exposures turned out to be the least susceptible to fouling. Thus, in an experiment on the colonization of various polymer-based materials by organisms in Karantinnaya Bay in the summer and autumn period of 2018, it was shown that the surfaces of the plates were densely populated by various meiobenthos fouling species: bryozoans, hydroids, tunicates, etc., and 94 species were registered as part of microphytofouling, including diatoms (67) and cyanobacteria (27) [8]. In addition, 20 species of diatoms, which form the basis of the floristic diversity of fouling, are common to masks and various polymer-based substrates.

On all experimental samples of the studied polymer-based materials, massive colonial species *Gr. marina* and *Licmophora abbreviata* were constantly observed, somewhat less commonly – *Tabularia tabulata* and *T. fasciculata*, which are characterized by adhesion to various natural and artificial substrates and formation of colonies that can also attach to polymer-based material.

As for face masks, we noted a similar picture, however, of 14 colonial fouling species detected, microalgae were mainly represented individually, without the formation of colonies.

In addition to the floristic study of fouling on masks, despite the low quantitative indicators, we presented the corresponding values of the detected species concerning the species richness (*S*), abundance (*N*), and biomass (*B*), using a counting chamber. After a two-month exposure, *S* varied within 10–15 species,



F i g. 4. Some diatoms in the fouling of single-use face masks surface, SEM: *Cocconeis placentula* (*a*), *C. guttata* (*b*), *Thalassionema nitzschioides* (*c*), *Cylindrotheca closterium* (*d*), *Achnanthes brevipes* (*e*), *Amphora pediculus* (*f*), *Karayevia amoena* (*g*), *Halamphora coffeiformis* (*h*). Scale bar: 1 µm (*a, f, g*), 2 µm (*e*, *h*), 10 µm (*b*, *c, d*)

N – 9200–13100 cells/cm^2, B – 0.001–0.02 mg/cm^2. After a one-year exposure, the corresponding values were as follows: S – 8–14 species, N – 4900–8400 cells/cm^2, and B – 0.01–0.03 mg/cm^2.

It is interesting to compare our information with data obtained from studying periphyton microalgae on experimental glass plates exposed in another part of the same bay from January 2007 to February 2008 for different periods (short-term – from 4 to 20 days; long-term – from 1 to 13 months) [4]. Right on the 20th day, a weak fouling of diatoms and then macroalgae seedlings was noticed on the plates, with its maximum in the spring at the end of a one-year exposure in water. A total of 99 taxa of microalgae are indicated from the following phyla: Bacillariophyta – 85, Dinophyta – 5, Chlorophyta – 4, Haptophyta – 2, and cyanobacteria – 3. 17 species of diatoms, 2 species of dinophytes, and one species each of haptophyte algae and cyanobacteria were shared by the glass plates and masks. During the cumulative exposure, the abundance of microalgae fouling of glass plates varied during the year from 26900 to 2180800 cells/cm^2, and the biomass varied within the range of 0.002–0.543 mg/cm^2.

It is shown in [12] that microplastics formed as a result of the degradation of masks are released into the environment almost from the first hours of its occurrence in it and contribute to an increase in the number and species diversity of the marine bacterial community. It is likely that masks become an attractive substrate for a variety of auto- and heterotrophic bacteria, which we have not studied.

Analysis of our own and literary sources showed that any substrates in the sea became colonized by microorganisms of plant and animal origin. As for microalgae, benthic diatoms have the greatest species diversity. Their richness and quantitative characteristics often depend on the type of substrate, season of the year, and environmental factors of the habitat.

The masks in Karantinnaya Bay were colonized by microalgae and cyanobacteria not so intensively as other anthropogenic substrates. This is especially true for the masks with a one-year exposure, which were subjected to the longest turbulent disturbances.

Conclusion

During the study period, 48 species from 5 phyla were noted: Cyanoprocaryota – 3 species, Bacillariophyta – 36, Dinophyta – 6, Haptophyta – 2, Ochrophyta – 1. After a two-month exposure, 30 species were found, and 40 species were found after a one-year exposure, 22 species were shared. For the first time for the bay, we have identified benthic species of diatoms *Cocconeis guttata* and *Karayevia amoena*. Out of 14 benthic typical colonial fouling species of diatoms on the surface of masks, cosmopolitan species *Tabularia fasciculata* showed the maximum occurrence (100 %). Solitary-living species were also recorded among the frequently encountered ones: potentially toxic *Halamphora coffeiformis* and bentoplanktonic *Cylindrotheca closterium*.

The features of the fouling of polymer-based single-use face masks at different exposure periods in the sea are the absence of formation of typical fouling species colonies and the lowest quantitative characteristics of microalgae compared to other anthropogenic and natural substrates: after a two-month exposure, the following species richness (*S*) was identified – 10–15 species, abundance (*N*) – 9200–13100 cells/cm^2, and biomass (*B*) – 0.001–0.02 mg/cm^2; after a one-year exposure: *S* – 8–14 species, *N* – 4900–8400 cells/cm^2, *B* – 0.01–0.03 mg/cm^2.

Biodegradation of single-use face masks exposed to seawater for a year under the influence of microalgae and cyanobacteria manifests itself to a weak degree. Therefore, it is necessary to study this process with a longer exposure, taking into account the physicochemical factors affecting the polymer-based substrate.

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About the authors:

Anna V. Bondarenko, Senior Research Associate, A. O. Kovalevsky Institute of Biology of the Southern Seas of RAS (2 Nakhimova Ave, Sevastopol, 299011, Russian Federation), Ph.D. (Biol.), **ORCID ID: 0000-0003-2202-4014**, *gonzurassa@mail.ru*

Larisa I. Ryabushko, Chief Research Associate, A. O. Kovalevsky Institute of Biology of the Southern Seas of RAS (2 Nakhimova Ave, Sevastopol, 299011, Russian Federation), Dr.Sci. (Biol.), **ORCID ID: 0000-0003-0443-9929**, *larisa.rybushko@yandex.ru*

Anastasiia A. Blaginina, A. O. Kovalevsky Institute of Biology of the Southern Seas of RAS (2 Nakhimova Ave, Sevastopol, 299011, Russian Federation), Ph.D. (Biol.), **ORCID ID: 0000-0001-7115-4427**, *aablagini@ibss-ras.ru*

Contribution of the authors:

Anna V. Bondarenko – material processing and manuscript writing

Larisa I. Ryabushko – statement of the task and objectives of the comprehensive study, manuscript editing

Anastasiia A. Blaginina – preparation of samples to obtain illustrations in the SEM

All the authors have read and approved the final manuscript.