Ecological assessment of zooplankton communities at the seaport of Temryuk (the Sea of Azov)

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Abstract. The taxonomic composition and dynamics of the abundance of holoplankton and meroplankton were studied in the estuary of the seaport Temryuk and in Temryuk Bay (background) in autumn 2018. The impact of the trading port and the Kuban River on the state of holoplankton and meroplankton was assessed. The abundance of holo- and meroplankton in the more desalinated and polluted estuary of the port, which borders the Kuban River, was 1.5–3 times lower than in the Temryuk Bay. In the composition of the copepods *Oithona davisae* and *Acartia tonsa*, up to half of non-viable individuals were found in the port estuary. In early autumn, the holoplankton was dominated by *Oithona davisa* and freshwater cyclopoid copepods; in Temryuk Bay, *O. davisae* prevailed; in meroplankton, larvae of mollusks wee ubiquitous. At the end of autumn, freshwater cyclopoid copepods and larvae of cirripede barnacles *Amphibalanus improvisus* were abundant in the port estuary; in the bay, along with *O. davisae*, brackish-water copepods *Eurytemora affinnis*, larvae of cirripede barnacles *A.improvisus* were abundant. The basis of the pool of merorplankton was species tolerant to water eutrophication and sulfide contamination of bottom sediments (*A. improvisus, Bittium reticulatum* and Bivalvia).

1 Introduction

Temryuk Bay was the most productive area of the Sea of Azov in the past. The Kuban River carries a huge amount of terrigenous suspension into the Sea of Azov with flows of desalinated water. Due to the river runoff, the water area of the bay is enriched with biogenic elements, suspended and dissolved organic substances, which are able to ensure the development of an abundant aquatic population. As a rule, in the zones the river and sea waters mix, the mass development of phytoplankton, bacteria, protozoa, planktonic detritophages and commercial plankton-eating planktonivores fishes occurs [1–2]. Highly eutrophic desalinated waters enter the Temryuk Bay from the Temryuk port, which is experiencing a strong anthropogenic impact. The port is located in the delta of the Kuban River, four kilometers from Temryuk. The area of the port water area is 22.68 km^2, the cargo turnover is over 2.9 million tons per year. The port handles liquid, bulk cargo, timber, grain and oil products. Under the influence of eutrophication, freshening and water pollution, specific environmental conditions determine the structure and dynamics of zooplankton development in this part of the Sea of Azov. In 2005–2006, the seasonal variability of the taxonomic composition and biomass of micro- and mesozooplankton, many species of which are biological indicators of habitat conditions, was studied [3]. However, for the Temryuk seaport with chronic technogenic pollution, such data are generally not available. It is known that the structure and abundance of meroplankton (larvae of benthic animals) is one of the main indicators of the state of benthic communities (benthos), its taxonomic composition and density [4].

The purpose of the work is to assess the ecological state of holo- and meroplankton in the Temryuk port and beyond (background) in the autumn season.

2 Materials and methods

Holo- and meroplanktonwas collected in autumn 2018 at five stations in the Temryuk port and at three background stations in the Temryuk Bay (Figure 1). The stations were located above the depths of 4.2–7.8 m.

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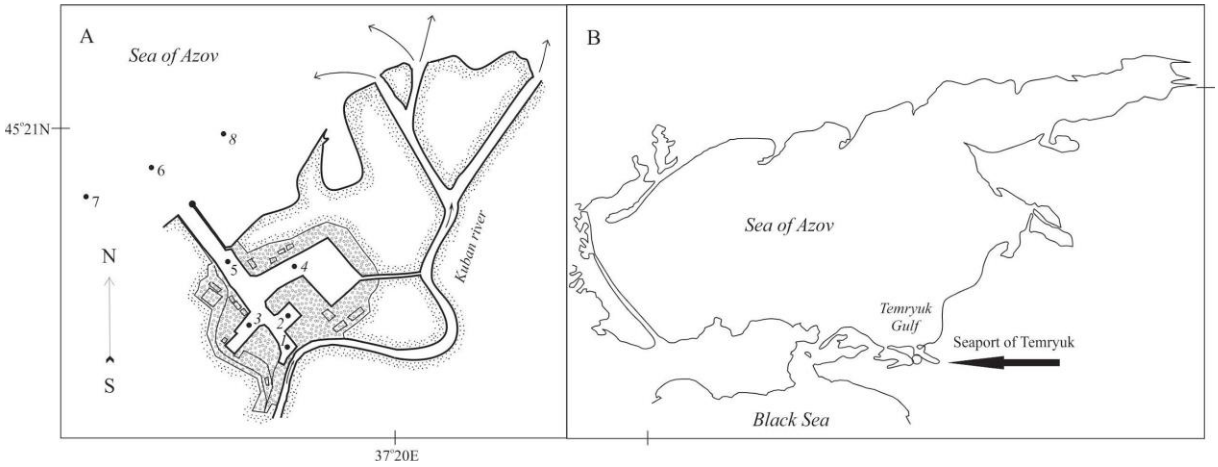

Fig. 1. The layout of zooplankton sampling stations area: A – port Temryuk, B – Sea of Azov (Temryuk Bay).

Zooplankton were sampled with a medium Judy net. The abundance of mesozooplankton was calculated considering the catchability coefficient of the net [5]. Biomass was calculated by the standard methods [6].

3 Results and discussion

Holoplankton. 11taxa were found in the holoplankton, including1 – Cladocera, 10 – Copepoda (Table 1). Among the copepods, brackish-water species – *Eurytemoraaffinis*, *Calanipedaaquaedulcis* – were observed [7].

The average number of holoplankton varied within 4.8–0.8 thousand ind./m^3 (average values – 2.7 thousand ind./m^3), biomass – 30.3–9.7 mg/m^3 (average values – 17 mg/m^3) (Figure 2a, b). The high numerical density of holoplanktonwas recorded in September at 24.5°C, and the low one - in November at 8.5°C. In September and October, in the composition of holoplankton (water temperature 16.9°C), marine cyclopoid copepods *Oithonadavisae* and *Halicyclops*and *Cyclops* developed. The contribution of the heat-loving copepod species *O. davisae* to the total abundance of holoplankton reached 57–58% [8–10].

Table 1. Taxonomic composition of holoplankton.

Taxa	Port	Bay
CLADOCERA		
Pleopispolyphemoides (Leuck.)	–	+
COPEPODA, CALANOIDA		
Acartiatonsa Dana	+	++
Acartiaclausi Giesbr. (small form)	+	+
Centropagesponticus Karav	–	+
Calanipedaaquaedulcis Krichagin, 1873	+	++
Eurytemoraaffinisaffinis (Poppe, 1880)	+	+++
COPEPODA, CYCLOPOIDA		
Oithonadavisae Ferrari, Orsi	+++	+++
*Halicyclops*sp.	+++	+
Cyclops sp.	+++	+
COPEPODA, HARPACTICOIDA		
*Harpacticus*sp.	+	+
Ectinosomaabrau (Kricz.)	+	+

Note. – the species is absent, + the species was found, ++ commonspecies, +++ massspecies

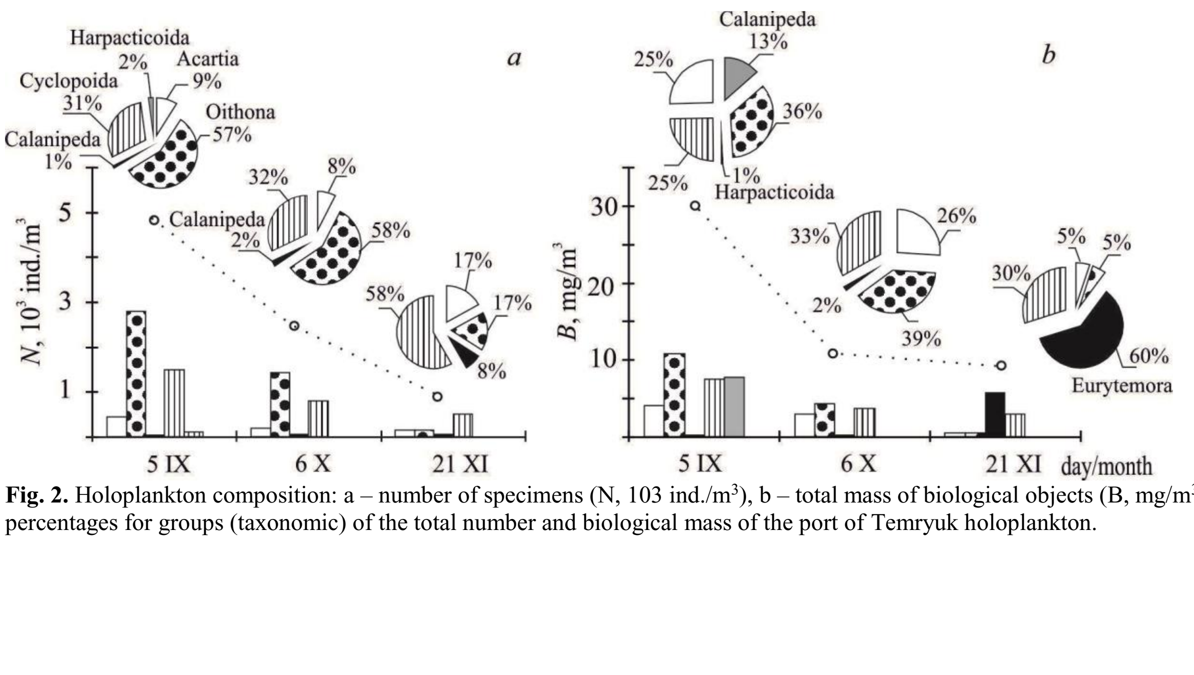

Fig. 2. Holoplankton composition: a – number of specimens (N, 103 ind./m^3), b – total mass of biological objects (B, mg/m^3), percentages for groups (taxonomic) of the total number and biological mass of the port of Temryuk holoplankton.

This species has recently invaded the Black and Azov Seas with the ballast waters of merchant fleet ships [4]. The share of oviparous females and nauplii reached 77–85%. In September, the abundance of the species was minimal (0.3 thousand ind./m^3) in the backwater area of the estuary (st. 1–3), and maximum (4.6 thousand ind./m^3) in the Glukhoi Canal (station 4). The absence of the species was observed in the most desalinated apex areas. The marine heat-loving calanoid copepods *Acartiatonsa* was not found in this area. As part of the population of marine species *O. davisae* and *A. tonsa,* up to half of non-viable individuals were observed in the port due to freshening of this area. Being a marine species living in estuaries and the coastal zone, *A. tonsa* breeds at a salinity of more than 2‰. The biomass of holoplankton formed at the expense of small cyclopoid copepods (61%) and large calanoid copepods A. tonsa (25%) and Calanipedaaquaedulcis (13%) (Figure 2c). In the population of C. aquaedulcis, along with copepodites (59%), sexually mature individuals (41%) were found. The lowest biomass values of copepods A. tonsa and O. davisae were recorded in November (no more than 5%). These species have a seasonal development: their density peaks are in summer; in October, at a temperature of 16–18°C the reproduction level gradually decreases and is completely absent in winter at lower water temperatures. A. tonsa is a thermophilic species that is present in the plankton of the Sea of Azov during the summer season and hibernates at the stage of resting eggs. In November, the biomass of holoplankton was mainly formed by freshwater Cyclopoida and Eurytemoraaffinnis (60%). The contribution of A. clausi (small form) to the total abundance of holoplankton was no more than 17% [11–14].

In the TemryukBay, the average abundance of holoplankton varied within 7.6–0.8 thousand ind./m^3 (average values, 3.9 thousand ind./m3), biomass, 24.9–63.5 mg/m^3 (average values, 42.4 mg/m^3) (Figure 3a, b).

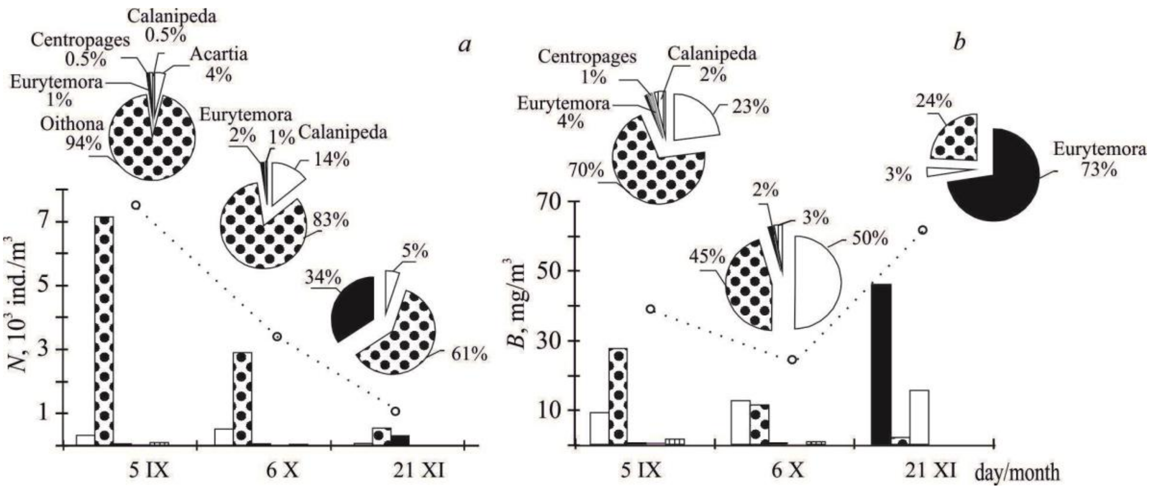

Fig. 3. Composition of holoplankton: a – number of specimens (N, 103 ind./m3), b – total mass of biological objects (B, mg/m3), percentages for groups (taxonomic) of the total number and biological mass of holoplankton outside Temryuk harbor.

The abundance of holoplankton was 1.5–2.5 times higher than in the port area. High levels of holoplankton abundance were observed in September (7600 ind./m^3) and October (3.4000 ind./m^3), when the share of O. davisae was significant in plankton (94–83% in abundance and 70–45% by biomass from the total amount of holoplankton) (Figure 3a, b). An increase in the number of O. davisae is associated to higher salinity compared to the port estuary. It is known that the water salinity in the original habitats of this species (the inland waters of Japan) is 28.6–32.3‰, while O. davisae was found in the San Francisco estuaries at a water salinity of 12–19‰. The share of other copepod species (copepods), such as A. tonsa, Calanipedaaquaedulcis, Centropagesponticus was insignificant. In September and October, up to 23–50% of the holoplankton biomass was formed by mature individuals and copepodites A. tonsa. In November, when a decline in the development of copepods began, E. affinnis made a significant contribution to the abundance (34% of the total amount of holoplankton) and biomass (73%). The E. affinis population consisted of 25% adults (males and females), 50% copepodites, and 25% nauplii. %). The contribution of A. clausi (small form) to the total abundance of holoplankton was no more than 5% [15–19].

Meroplankton. Five taxa were identified in meroplankton, among which two are Polychaeta, one is Bivalvia, one is Gastrpoda, and one is Cirripedia (Table 2). The proportion of meroplankton in zooplankton averaged 16.3% in the port and 15.6% in the bay.

Table 2. Taxonomic composition of holoplankton

Taxa	Port	Bay
POLYCHAETA		
Polydoracornuta Bosc	++	++
Nereidae gen sp.	+	+
BIVALVIA		
Anadarakagochinensis (Tokunaga)	+	+
Bivalvia	+++	+++
GASTROPODA		
Bittiumreticulatum (daCosta)	+++	+
CIRRIPEDIA		
Amphibalanusimprovisus (Darwin)	+++	+++

Note. – the species is absent, + the species was found, ++ commonspecies, +++ massspecies

The average number of meroplankton in the port of Temryuk varied within 0.1–1.1 thousand ind./m^3 (average values – 0.5 thousand ind./m^3), biomass – 1.8–7.6 mg/m^3 (average values – 4 mg/m^3) (Figure 4a, b).

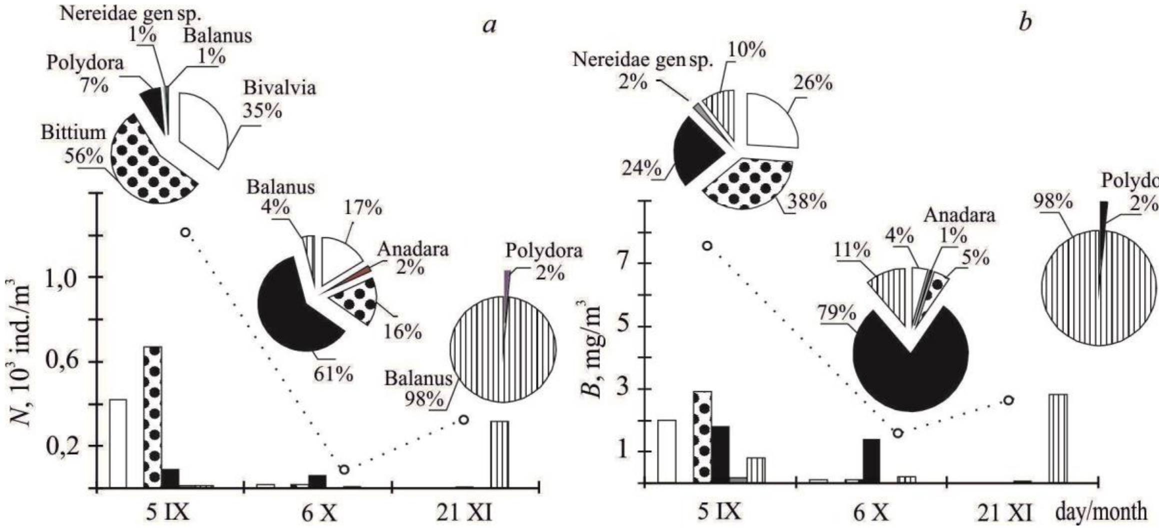

Fig. 4. Composition of meroplankton: a – number of specimens (N, 103 ind./m3), b – total mass of biological objects (B, mg/m^3), percentages for groups (taxonomic) of the total number and biological mass of meroplankton in the port of Temryuk.

The largest number of larvae of bottom invertebrates was found in September, the smallest – in October. In September, in the port estuary (st. 1–2), the abundance of larvae of bivalve and larvae of gastropod mollusks Bittiumreticulatum reached 1.5–1.2 thousand ind./m^3, biomass 6.1–7.2 mg/m^3. The contribution of these organisms to the average abundance reached 56–35%, and to the biomass – 38–26%. In October, larvae of polycheates Polydoracornuta (61–79%) dominated in the composition of meroplankton [20–23].

The density of meroplankton was three times higher than in the port area. The average abundance of meroplankton in the bay varied within 0.02–1.8 thousand ind./m^3, biomass – 0.4–9.8 mg/m^3 (average values – 4.4 mg/m^3) (Figure 5a, b).

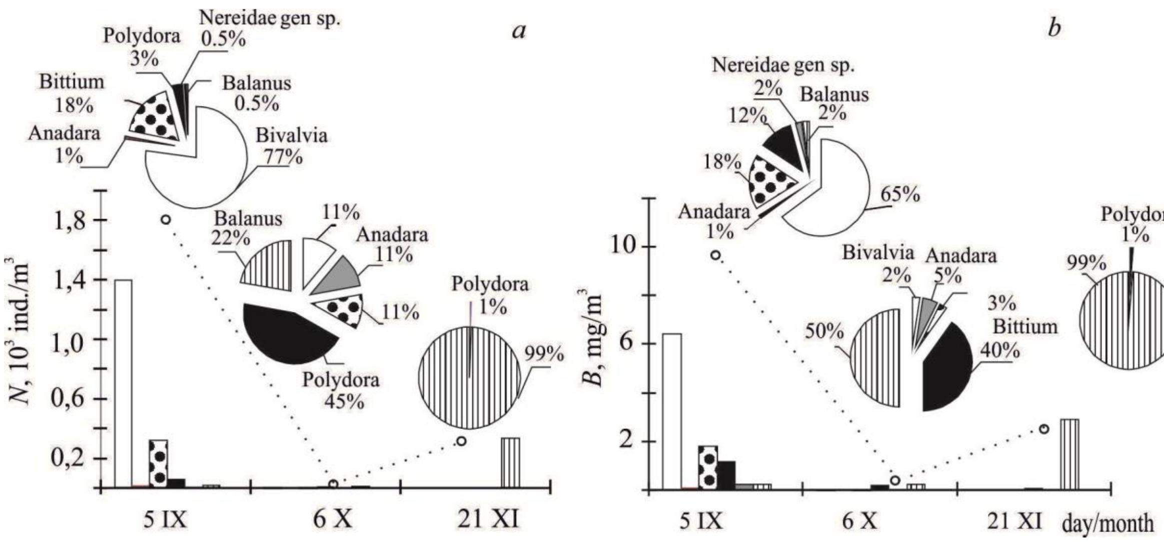

Fig. 5. Composition of meroplankton: a – number of specimens (N, 103 ind./m3), b – total mass of biological objects (B, mg/m3), percentages for groups (taxonomic) of the total number and biological mass of meroplankton outside Temryuk harbor.

The autumn dynamics of meroplankton abundance in the Temryuk Bay was similar to that in the port area. In September, larvae of bivalve Bivalvia (77–65% of the total amount of meroplankton) dominated; in October, larvae of polycheates P. cornuta (61–79%) were dominant, while in November, larvae of cirripede barnacles Amphibalanusimprovisus (99%) prevailed. The meroplankton pool in and outside the port was dominated by species tolerant to water eutrophication and sulfide contamination of bottom sediments [7] (*A. improvisus, B. reticulatum* and unidentified bivalve mollusks).

4 Conclusion

An assessment of the ecological state of the zooplankton in the port of Temryuk, located on the Taman Peninsula of the Sea of Azov and borders the Kuban River was carried out. The abundance of *holo- and meroplankton* in the more desalinated and polluted port estuary was 1.5–3 times lower than in Temryuk Bay. In the composition of the copepods *Oithonadavisae* and *Acartiatonsa*, up to half of non-viable individuals were found in the port estuary. In early autumn, the holoplankton was dominated by oid copepods *Oithonadavisa* and freshwater cyclopoid copepods; in Temryuk Bay, copepods *O. davisae* were dominant; in meroplankton, larvae of mollusks were ubiquitous. At the end of autumn, freshwater cyclopoid copepods and larvae of cirripede barnacles *Amphibalanusimprovisus* were abundant in the port estuary; in the bay, along with *O. davisae*, brackish-water copepods *Eurytemoraaffinnis* and larvae of cirripede barnacles A. improvisus were abundant. The *merorplankton* pool was mainly based on the eutolerant species which are resistant to waters and sulfide contamination of bottom sediments (*A. improvisus, Bittiumreticulatum and unidentified bivalves*).

The results obtained give an idea of the ecological state of the autumn zooplankton in the Temryuk port and may be useful for further monitoring of this area of the Sea of Azov.

References

1. *The Ctenophore Mnemiopsis leidyi (A. Agassiz) in the Azov and Black Seas*, Collected papers (BKI, Rostov on Don, 2000)
2. P.R. Makarevich, *Planktonic Algalcenoses of Estuarine Ecosystems: Barents, Kara and Azov Seas* (Nauka, Moscow, 2007)
3. Zh.P. Selifonova, Seasonal Dynamics of Micro- and Mesoplankton of the Temryuk Estuarine Pelagic Ecosystem of the Sea of Azov, Inland Water Biol. **4(2)**, 182–191 (2011)
4. Zh.P. Selifonova, *Ecosystems of bays and harbours of the northeastern Black Sea and the Sea of Azov* (AUMSU, Novorossiysk, 2018)
5. E.B. Pavelieva, Yu.I. Sorokin, Assessment of zooplankton catchability by various fishing gear, Inform. Bull. of the IBIW of the USSR Acad. of Sci. **15**, 75–80 (1972)
6. F.D. Mordukhai Boltovskoi, *Materials on the Average Weight of Aquatic Invertebrates of the Don River Basin, Problems of Hydrobiology of Inland Waters*, Proceedings of a problematic and thematic meeting, Iss. 2 (Publ. house ZIN Acad. of Sci. of the USSR, Moscow; Leningrad, 1954), pp. 223–241
7. Yu.I. Sorokin, O.N. Burkatsky, Content of labile sulfides in bottom sediments of the central part of the Sea of Azov: Impact on bottom zoocenoses, Oceanol. **47(5)**, 729–735 (2007)
8. A.E. Balanovskiy, M.G. Shtaiger, V.V. Kondratyev, A.I. Karlina, Determination of rail steel structural elements via the method of atomic force microscopy, CIS Iron and Steel Rev. **23**, 86–91 (2022)
9. V.A. Ershov, I.A. Sysoev, V.V. Kondrat'ev, Determination of aluminum oxide concentration in molten cryolite-alumina, Metallurgist **57(3–4)**, 346–351 (2013)
10. E.F. Denisov, M.Z. Yamilev, E.A. Tigulev, V.V. Pshenin, Analysis of the current level of technologies for determining the location of non-metallic underground services, Oil Industry, **2022(9)**, 121–125 (2022), DOI: 10.24887/0028-2448-2022-9-121-125
11. V.V. Kondrat'ev, V.O. Gorovoy, A.D. Kolosov, R.V. Kononenko, V.Y. Konyukhov, Description of the complex of technical means of an automated control system for the technological process of thermal vortex enrichment, J. of Phys.: Conf. Ser. **1661(1)**, 012101 (2020)
12. S.V. Klyuev, N.F. Kashapov, O.V. Radaykin, L.S. Sabitov, A.V. Klyuev, N.A. Shchekina, Reliability coefficient for fibreconcrete material, Construct. Mater. and Prod. **5(2)**, 51–58 (2022), Retrieved from: https://doi.org/10.58224/2618-7183-2022-5-2-51-58
13. I.G. Vidayev, N.V. Martyushev, A.S. Ivashutenko, A.M. Bogdan, The resource efficiency assessment technique for the foundry production, Adv. Mater. Res. **880**, 141–145 (2014), DOI: 10.4028/www.scientific.net/AMR.880.141
14. E. Volneikina, O. Kukartseva, A. Menshenin, V. Tynchenko, K. Degtyareva, Simulation-Dynamic Modeling Of Supply Chains Based On Big Data, *INFOTEH-JAHORINA, INFOTEH 2023*, 22nd Int. Symp. (2023), DOI: 10.1109/INFOTEH57020.2023.10094168
15. V.L. Tatarintsev, L.M. Tatarintsev, F.K. Ermekov, Yu.S. Lisovskaya, Assessment of the agroecological state of agricultural landscapes to improve their sustainability, Sustainable developm. of mountain areas **14(1)**, 76–87 (2022), DOI: 10.21177/1998-4502-2022-14-1-76-86
16. I.A. Sysoev, V.A. Ershov, V.V. Kondrat'ev, Method of Controlling the Energy Balance of Electrolytic Cells for Aluminum Production, Metallurgist **59(5–6)**, 518–525 (2015), Retrieved from: https://doi.org/10.1007/s11015-015-0134-1
17. E.A. Efremenkov, N.V. Martyushev, V.Y. Skeeba, M.V. Grechneva, A.V. Olisov, A.D. Ens, Research on the Possibility of Lowering the Manufacturing Accuracy of Cycloid Transmission Wheels with Intermediate Rolling Elements and a Free Cage, Appl. Sci. **12**, 5 (2022), DOI: 10.3390/app12010005
18. N.V. Martyushev, D.A. Bublik, V.V. Kukartsev, V.S. Tynchenko, R.V. Klyuev, Y.A. Tynchenko, Y.I. Karlina, Provision of Rational Parameters for the Turning Mode of Small-Sized Parts Made of the

29 NK Alloy and Beryllium Bronze for Subsequent Thermal Pulse Deburring, Mater. **16**, 3490 (2023), DOI: 10.3390/ma16093490

19. B.V. Malozyomov, N.V. Martyushev, V.Y. Konyukhov, T.A. Oparina, N.A. Zagorodnii, E.A. Efremenkov, M. Qi, Mathematical Analysis of the Reliability of Modern Trolleybuses and Electric Buses, Mathem. **11**, 3260 (2023), DOI: 10.3390/math11153260
20. B.V. Malozyomov, N.V. Martyushev, S.N. Sorokova, E.A. Efremenkov, D.V. Valuev, M. Qi, Mathematical Modelling of Traction Equipment Parameters of Electric Cargo Trucks, Mathem. **12**, 577 (2024), DOI: 10.3390/math12040577
21. A.A. Korshak, V.V. Pshenin, Calculation of phase transitions in condensation units for recovery of oil and oil products vapors, Oil Industry **2021(6)**, 98–101 (2021), DOI: 10.24887/0028-2448-2021-6-98-101
22. M.Z. Yamilev, V.V. Pshenin, D.S. Matveev, D.S. Podlesniy, T.I. Bezimyannikov, The use of compact inspection devices for monitoring the technical condition of pipelines in protective cases, Oil Industry **2022(2)**, 106–110 (2022), DOI: 10.24887/0028-2448-2022-2-106-110
23. M. Ozkaleli, A. Erdem, Biotoxicity of TiO_2 Nanoparticles on Raphidocelis subcapitata Microalgae Exemplified by Membrane Deformation, Int. J. Environ. Res. Public Health. **15(3)** (2018), Retrieved from: https://doi.org/10