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Article

Fauna and ecological features of pyritic cinder reservoir insects (using the example of the Vologda Region)

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Abstract. In June–July 2021, the entomofauna of a storage facility for pyrite cinders in the vicinity of Cherepovets was studied. A total of 161 species of insects from 64 families and 8 orders were found. The orders with the greatest species diversity were Coleoptera, Hymenoptera and Diptera. Most of the species reported are widespread in the region, but rare, including protected, species are also found. The richest species composition of insects is on the tops and slopes of the sludge reservoir. The fauna includes numerous hortobiont species that feed on flowers, pollen and nectar and have good dispersal abilities. A small number of phyllophagous insects was found. At the top and slopes of the sludge reservoir, ants are dominant. A total of 5 species of ants were found in the study area.

Keywords: entomofauna, species composition, environmental groups, industrial waste

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Научная статья**Фауна и экологические особенности насекомых шламонакопителя пиритных огарков (на примере Вологодской области)**Ю.Н. Белова^{id}, Н.С. Колесова*^{id}*Вологодский государственный университет, 160000, Россия, Вологодская область, г. Вологда, ул. Ленина, д. 15***nbalukova@yandex.ru*

Аннотация. В июне–июле 2021 г. исследована энтомофауна хранилища пиритных огарков в окрестностях г. Череповец. Всего обнаружен 161 вид насекомых из 64 семейств и 8 отрядов. Наибольшее видовое разнообразие свойственно для отрядов Coleoptera, Hymenoptera и Diptera. В основном представлены виды, широко распространенные в области, однако отмечены редкие, в том числе охраняемые виды. Наиболее богат видовой состав насекомых вершин и склонов шламонакопителя. В составе фауны многочисленны виды-хортобионты, питающиеся цветками, пыльцой и нектаром, обладающие хорошими миграционными способностями. Отмечена низкая численность насекомых-филлофагов. На вершине и склонах шламонакопителя доминантами являются муравьи. Всего в районе исследования было встречено 5 видов муравьев.

Ключевые слова: энтомофауна, видовой состав, экологические группы, промышленные отходы

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Introduction

Pyrite cinders are industrial mineral substrate from sulfuric acid production using the pyrite concentrate roasting technique (Makarov et al., 2012). Pyrite cinders are finely-dispersed purplish, brown-red powder (Makarov et al., 2020) which predominantly consists of iron oxides (50–70%) and silicon with a slight infusion of sulphur (1–2%), copper (0.33–0.47%), zinc (0.42–0.35%), lead (0.32–0.58%), valuable metals (up to 10–20 grams per ton) and other metals (Gulayeva et al., 2017). There are four huge waste disposal facilities containing more than 1 million tons of pyrite cinders as waste products of sulfuric acid production in Russia. The biggest one (12 million tons) is located on the territory of the “Apatit” Company, not far from the city of Cherepovets, Vologda Oblast, in the north-west European part of Russia (Melentyev, 2015). The cinders are stored using the hydraulic method in slurry reservoirs, special uncovered containers of large size to collect the cinders before they go to the special storage area.

Under the influence of environmental factors, the contents of a slurry reservoir undergo natural processes connected with precipitation accumulation, oxidation, and colonization by living organisms the features and variety of which change over time. Invertebrates play an important role in such assemblages especially at an early stage of their formation (Suktsessii..., 1993). Insects are the first to appear on the surface of the anthropogenic substrates (Mordkovich and Lyubechansky, 2019).

The research showed that the invertebrate fauna of the anthropogenic substrates of industrial waste is formed due to active invasion of species from the surrounding areas or their passive dispersal with the air streams, or with soil which is brought to improve the environment and remediate, etc. (Dulkin et al., 1969; Ereemeeva and Luzyanin, 2015; Mordkovich and Lyubechansky, 2019; Rusakov et al., 2013; Suktsessii..., 1993). At the beginning, an assemblage of soil animals forms which influence the processes of soil formation and vegetation cover, either directly or indirectly (Suktsessii..., 1993). The phytocenoses that appeared are actively colonized by invertebrates, the diversity of their species depends on the age of the dumps and the vegetation cover which has been formed. The more vegetation types and flowering herbaceous plants are found, the greater the species diversity is (Galinovsky and Kritskaya, 2014). In general, the number of species on the dumps is low, but animal populations may be even denser in comparison with natural assemblages (Bogorodskaya et al., 2010; Ereemeeva and Luzyanin, 2017; Lyubechansky et al., 2019; Mordkovich and Lyubechansky, 2019; Suktsessii..., 1993). The species diversity and population density of species with dispersal behavior are greater. Coleoptera (Carabidae, Staphylinidae) and ants predominate on the ground cover (Blinova, 2015; Blinova et al., 2015; Ereemeeva and Luzyanin, 2016; Ereemeeva et al., 2013, 2015a, b; Luzyanin and Ereemeeva, 2016; Mordkovich and Lyubechansky, 2019). Hemiptera (Acanthosomatidae, Anthocoridae, Pentatomidae, Cicadellidae), Diptera and Thysanoptera predominate among the insects in the grass (Dulkin et al., 1969).

Composition and behavior patterns of the insect assemblages in anthropogenic substrates are of great interest and relevance, and numerous studies deal with coal industry dumps. The problems of animal population formation and development under the influence of remediation actions and over time have been studied (Bespalov, 2016; Bespalov and Belanov, 2020; Ereemeeva et al., 2013, 2015a; Ereemeeva and Luzyanin, 2015, 2017; Luzyanin and Ereemeeva, 2016; Mordkovich and Lyubechansky, 2019; Rusakov et al., 2013; Suktsessii..., 1993). Many research works on soil mesofauna and herpetobionts use insects as a subject of study. Similar studies in other types of industries are not very numerous and contain little data about fauna in slurry reservoirs and dumps. The fauna and Coleoptera population in phosphogypsum stacks (phosphorus production) were studied (Galinovsky and Kritskaya, 2014; Kritskaya and Galinovsky, 2014). There have been some studies on insect fauna in dumps from metal production: aluminum (Dulkin et al., 1969), zinc and lead (Blinova, 2015).

This research is considered topical as there are no works on insect fauna in pyrite cinder dumps. The aim of the current study is to analyze the composition and characteristic features of entomofauna in sludge reservoirs of pyrite cinders.

Materials and methods

The field material was collected in June–July, 2021 on the sludge reservoir of pyrite cinders on the territory of “Apatit” Company, 12 km from Cherepovets (Fig. 1). There are ponds in the middle of the sludge reservoir; there is an enclosing dam and a drain along its periphery. The soil in the reservoir mainly consists of pyrite cinders and ash with the majority of their elements in a static form; there are insertions of sulfur and pyrite (FeS_2). The soil samples contained Fe^{3+} , Ba^{2+} , Mn^{2+} , Ca^{2+} , Al^{3+} , Cu^{2+} , Cd^{2+} , Zn^{2+} , Hg^{2+} . Biotesting of the soil showed different degrees of contamination: from strong in the central part of the sludge reservoir to weak and no contamination on the periphery, including the enclosing dam (Bulycheva, 2022).



Fig. 1. Sludge reservoir of pyrite cinders in the vicinity of Cherepovets. The orange line shows the border of the sludge reservoir, the yellow line shows the border of the adjacent zone, the studied areas are marked with blue filling.

Table 1. Characteristics of the studied areas. The names of the plant associations are given according to the research report "Assessment of Biological Diversity and Identification of Officially Rare Species of Plants and Animals at the Pyrite Cinder Sludge Reservoir Site (PCSR) No 1, 2, 3 and along the perimeter in the 300-meter zone, for the development of a conservation project for the complex of hydraulic structures PCSR No 1, 2, 3 located on the territory of the "Apatit" Phosphorus Complex".

No.	Area	Vegetation type	Plant association
1	perimeter of the sludge reservoir (adjacent territory)	weed-ruderal, meadow and forest	willow herb-tansy-cocksfoot
2	sludge reservoir foot	forest	large-grass birch, large-grass alder
3	slope of sludge reservoir (edge)	weed-ruderal	beaked parsley, umbel-hawk weed-brown knapweed-tansy
4	sludge reservoir top (storage site)	weed-ruderal	sweet clover-various grasses, meadow vetchling-various grasses, willow herb-sweet clover-meadow vetchling

The materials were collected in several areas: outside along the perimeter, at the foot, on the slopes and on the top of the enclosing dam of the sludge reservoir (Table 1, Figs. 1, 2). The following methods were used to collect the material:

- 1) manual collection from herbaceous, shrubby and woody plants, under ground covers;
- 2) collection of insects of the herbaceous layer using an entomological net;
- 3) study of damage to herbaceous and woody plants.

The process of collecting ground insects with traditional pitfall traps was not possible, because particles of pyrite cinders in the dumps are significantly compacted and cemented into dense stony aggregates under the influence of surface factors (mainly water) (Makarov et al., 2021).

To determine insect species, the identification keys were used for all systematic groups (Mozolevskaya et al., 2004; *Opredelitel nasekomykh...*, 1948), as well as for the orders Dragonflies (*Opredelitel nasekomykh...*, 1964), Coleoptera (Benkovsky, 1999; *Opredelitel nasekomykh...*, 1965), Hymenoptera (*Opredelitel nasekomykh...*, 1978), Diptera (Haarto and Kerppola, 2007; *Opredelitel nasekomykh...*, 1969, 1970; Stakelberg, 1933) and Lepidoptera (Tatarinov and Dolgin, 1999). The genus and species of some representatives of Aphididae, Ichneumonidae, Chalcididae have not been identified. The species of some representatives of *Lathrobium* (Staphylinidae), *Tenthredo* (1 of the 4 collected species is undetermined) (Tenthredinidae), *Chaoborus* (Chaoboridae), *Platycheirus* (Syrphidae) have not been identified. When counting the number of species, each named taxon is taken into account as a unit. The names of the taxa are given according to the Fauna Europaea resource¹.

Results

Taxonomic analysis of fauna

The insects recorded on the pyrite cinder sludge reservoir and its immediate surroundings belong to 161 species from 64 families and 8 orders (Tables 2, 3). The representatives of Coleoptera, Hymenoptera and Diptera show the highest species diversity (Table 3). Among beetles, leaf beetles (Chrysomelidae) predominate in terms of species richness, true bees (Apidae) predominate among Hymenoptera, and hoverflies (Syrphidae) predominate among Diptera.

¹ Fauna Europaea. Web page. URL: <https://fauna-eu.org>. (accessed: 30.08.2021).

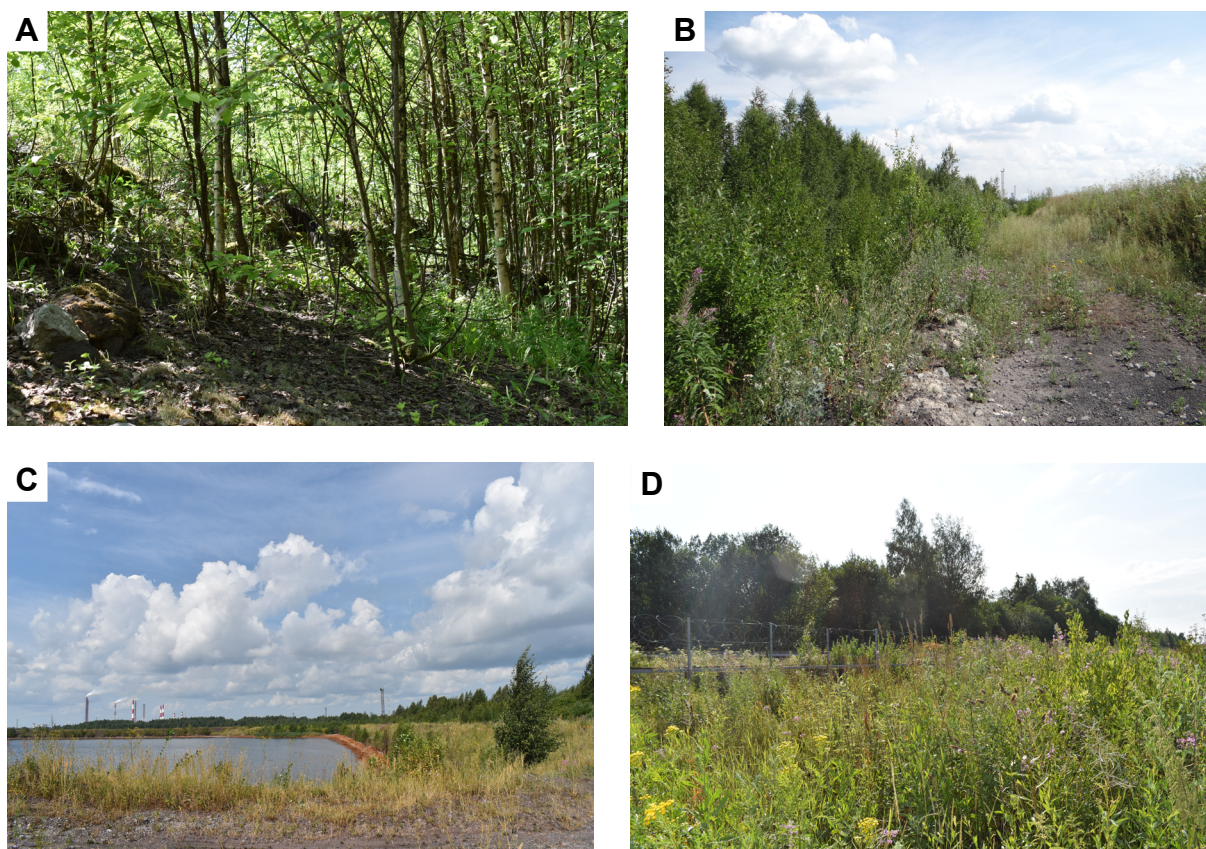


Fig. 2. Surveyed areas of the sludge reservoir: **A** – foot, **B** – slope (edge), **C** – top, **D** – perimeter (adjacent territory). Photograph by N.S. Kolesova and Yu.N. Belova.

Species diversity and spatial distribution of insects

The analysis of the spatial distribution of insects shows that a greater number of insect species is found on the tops and slopes of the sludge reservoir in comparison with its foot and perimeter (Fig. 3).

Only a small number of the species is observed in all parts of the sludge reservoir and in its surroundings. These are *Apis mellifera*, *Bombus bohemicus*, *B. lapidarius*, *B. lucorum*, *B. pascuorum*, *B. semenoviellus*, *B. terrestris*, *Formica cinerea* and *Polyommatus icarus*. The rest of the species are not so widespread and colonize a particular biotope.

The perimeter of the sludge reservoir

Along the perimeter of the sludge reservoir there are tall grasses and areas with woody vegetation: gray alder *Alnus incana* (L.) Moench and silver birch *Betula pendula* Roth. The golden alder leaf beetle *Plagiosterna aenea* is found in great numbers in alders in wet areas. The alder beetle *Agelastica alni* is found in large numbers on alders and occasionally on birches. In tall grass areas, the wart-biter *Decticus verrucivorus*, the field grasshopper *Chorthippus brunneus*, and the Italian shield bug *Graphosoma lineatum* are numerous.

The foot of the sludge reservoir

At the foot of the sludge reservoir there are young small-leaved forests. In the crowns of the trees there are adults of the May beetle *Melolontha hippocastani*, bugs that feed on plant sap *Acanthosoma haemorrhoidale*, and predators *Anthrenus nemorum*. Sucking insects such as alder psyllid *Psylla alni* are common on young alder shoots. Among the herbaceous vegetation, click beetles *Ampedus balteatus* have been observed, the adults feed on the green parts of plants, and the larvae develop in deciduous wood. In the grass stand under the forest canopy, predatory soft-bodied beetles *Cantharis livida*, *C. pellucida* and *Rhagonycha testacea* are found in great numbers. The adults of ground beetles *Limodromus assimilis* and *Carabus granulatus*, which are common in deciduous forests, are found on the soil surface and in the litter.

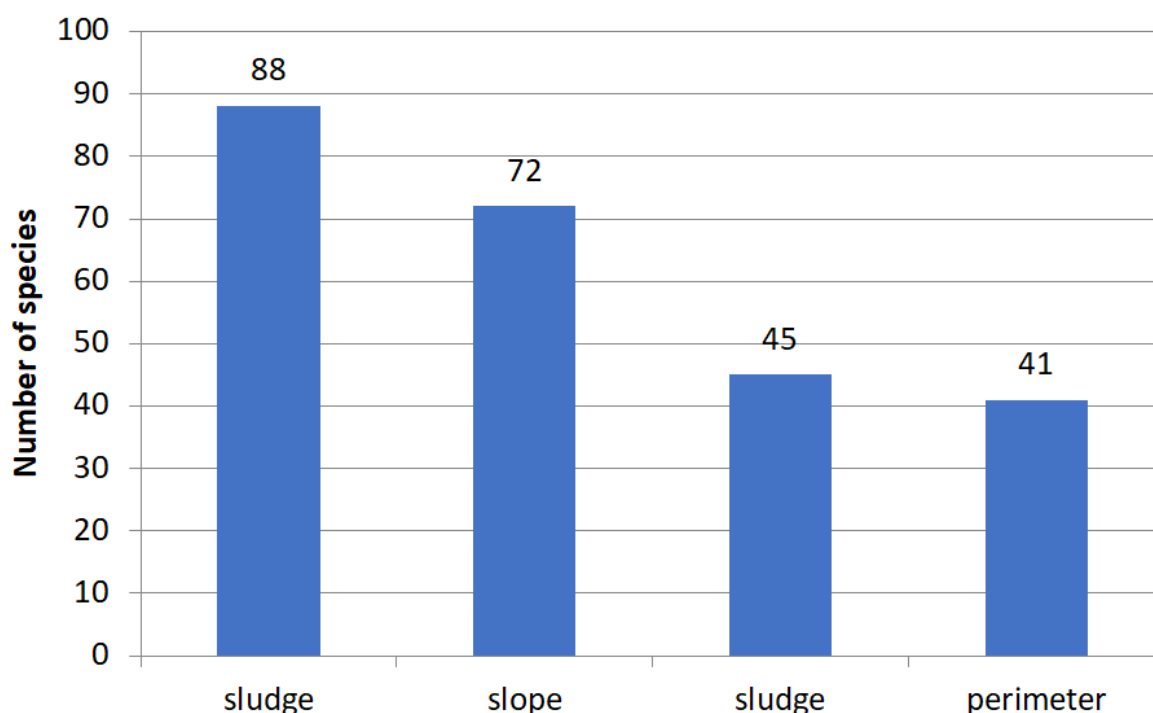


Fig. 3. Spatial distribution of insects along the profile of the sludge reservoir of pyrite cinders.

There are ditches along the dam where larvae of many insects develop. The adult insects are found on the slopes and top of the dumps: dragonflies, marsh beetles, horseflies, and hoverflies from the genera *Neoascia* and *Eristalis*.

The slopes and top (storage area) of the sludge reservoir

The observations show that there is a low number of phyllophagous insects along the border of woody and herbaceous vegetation in the crowns of deciduous trees (birch, alder, aspen, willow). On the young shoots of aspens and willows, there are individuals of the leaf beetles *Cryptocephalus octopunctatus*, *Cr. androgyne* and *Phratora vitellinae*, and weevils *Phyllobius arborator*. All of them feed on the surface of leaves of the host plants as adults, and as larvae either on the leaves (*Phratora*) or in the soil and leaf litter (*Phyllobius*, *Cryptocephalus*). There are insect larvae that develop in leaf tissues and inside rolled leaf blades: *Scolioneura betuleti* (Fig. 4A), *Agromyza alnibetulae* (Fig. 4B), *Harmandiola globuli* (Fig. 4C), *Deporaus betulae*, *Byctiscus populi*. The low number of phyllophages is probably determined by the presence of a film of dust-like particles on the surface of the leaves, deposited from the air during work at the sludge storage site (Fig. 4D), as well as the impact of emissions from the nearby industrial workshops of “Apatit”, where phosphate-based fertilizers, phosphoric and sulfuric acids, ammonia and ammonium nitrate are produced². A decrease in the number of phyllophagous insects under the influence of emissions in the impact zone of an industrial enterprise (copper smelter) was reported by E.A. Belskaya and E.L. Vorobeichik (2013).

It is of great interest to note that a parasitic wasp *Aulacus striatus* was found, which has only once been observed previously in the north and north-west of European Russia (Sundukov and Leley, 2015, 2019). This is the second time the species was recorded in the north of European Russia (within the boundaries of this region, according to the “Annotated catalogue of the Hymenoptera of Russia” (Belokobylsky et al., 2019)). Both times it occurred in the Vologda Region, in 1983 and 2021 (Sundukov and Leley, 2015). *Aulacus striatus* is a specialized parasite of horntails of the genus *Xiphydria*. Adult insects are found on damaged or fallen trees (alder, birch, and aspen) in which horntail larvae develop, as well as on umbelliferous flowers (*Apiaceae*) (Bulanova, 2022; Sundukov and Leley, 2015; Zlatanov et al., 2017). This time *Aulacus striatus* and *Xiphydria camelus* were found on one of the drying birches on the top of the dump (Fig. 5).

² Apatit JSC (Vologda Region). Web page. URL: https://www.phosagro.ru/about/holding_cherepovets (accessed: 06.04.2024).

Table 2. Composition of the insect fauna of pyrite cinder dumps and ecological features of species. Biotopes: 1 – perimeter of the sludge reservoir, 2 – foot of the sludge reservoir (birch grove), 3 – slope of the sludge reservoir (edge), 4 – top of the sludge reservoir (weed-ruderal vegetation); ecological group according to the tier: H – herbivorous, Hd – herbivorous, D – dendrobionts, T – tamnionts, Ht – hortobionts; trophic group (imago): An – anthrophagous or anthophilous, A – aphagous, Hm – hemophagous, S – saprophagous, Ph – phyllophagous, P – predatory, E – euryphagous; ability to move: H – high, M – moderate, W – weak.

Family	Species	Biotope				Ecological group according to the layer	Trophic group	Dispersal ability
		1	2	3	4			
		Order Odonata						
Coenagrionidae	<i>Coenagrion hastulatum</i> (Charpentier, 1825)			+		Ht	P	H
Aeshnidae	<i>Aeshna grandis</i> (L., 1758)	+				Ht	P	H
	<i>Sympetrum flaveolum</i> (L., 1758)	+			+	Ht	P	H
Libellulidae	<i>Sympetrum sanguineum</i> (Müller, 1764)	+			+	Ht	P	H
	<i>Sympetrum vulgatum</i> (L., 1758)	+				Ht	P	H
		Order Orthoptera						
Tettigoniidae	<i>Decticus verrucivorus</i> (L., 1758)	+				Ht	E	M
Acrididae	<i>Chorthippus brunneus</i> (Thunberg, 1815)	+				Ht	Ph	M
		Order Hemiptera						
Aphrophoridae	<i>Lepyronia coleoptrata</i> (L., 1758)			+		Ht	Ph	M
	<i>Philaenus spumarius</i> (L., 1758)			+		Ht	Ph	W
Cicadellidae	<i>Cicadella viridis</i> (L., 1758)	+		+		Ht	Ph	M
Psyllidae	<i>Psylla alni</i> (L., 1758)		+			T, D	Ph	S
Aphididae	Aphididae	+		+	+	Ht, T	Ph	S
Acanthosomatidae	<i>Acanthosoma haemorrhoidale</i> (L., 1758)		+			T, D	Ph	S
Anthocoridae	<i>Anthocoris nemorum</i> (L., 1761)		+			T, D	P	S
	<i>Carpocoris purpureipennis</i> (De Geer, 1773)		+		+	Ht	Ph	M
	<i>Dolycoris baccarum</i> (L., 1758)			+		Ht	Ph	M
Pentatomidae	<i>Graphosoma lineatum</i> (L., 1758)	+				Ht	Ph	M
	<i>Palomena prasina</i> (L., 1761)				+	T, D	Ph	M
		Order Coleoptera						
	<i>Amara aenea</i> (De Geer, 1774)				+	H	E	M
	<i>Amara similata</i> (Gyllenhal, 1810)				+	H	E	M
Carabidae	<i>Carabus granulatus</i> L., 1758		+			H	P	M
	<i>Limodromus assimilis</i> (Paykull, 1790)		+			H	P	M
	<i>Notiophilus palustris</i> (Duftschmid, 1812)		+			H	P	W

Family	Species	Biotope				Ecological group according to the layer	Trophic group	Dispersal ability
		1	2	3	4			
Dytiscidae	<i>Acilius canaliculatus</i> (Nicolai, 1822)				+	Hd	P	M
Cetoniidae	<i>Oxythyrea funesta</i> (Poda, 1761)				+	Ht	An	M
	<i>Protaetia cuprea</i> (Fabricius, 1775)				+	Ht, T	An	H
Melolonthidae	<i>Melolontha hippocastani</i> Fabricius, 1801			+		T, D	Ph	M
Staphilinidae	<i>Lathrobium</i> sp.			+	+	H	P	M
Cantharidae	<i>Cantharis livida</i> L., 1758		+		+	Ht	P	M
	<i>Cantharis nigricans</i> Muller, 1766			+	+	Ht	P	M
	<i>Cantharis pellucida</i> Fabricius, 1792		+		+	Ht	P	M
	<i>Rhagonycha fulva</i> (Scopoli, 1763)			+		Ht	P	M
	<i>Rhagonycha testacea</i> (L., 1758)		+			Ht	P	M
	<i>Cyphon coarctatus</i> Paykull, 1799		+			Ht	S	W
Scirtidae	<i>Cyphon padi</i> (L., 1758)				+	Ht	S	W
	<i>Cyphon paykulli</i> Guerin, 1843				+	Ht	S	W
	<i>Cyphon variabilis</i> (Thunberg, 1787)				+	Ht	S	W
Elateridae	<i>Ampedus balteatus</i> (L., 1758)		+			Ht	Ph	M
Nitidulidae	<i>Brassicogethes aeneus</i> (Fabricius, 1775)		+			Ht	An	M
Coccinellidae	<i>Coccinella quinquepunctata</i> L., 1758				+	Ht	P	M
	<i>Coccinella septempunctata</i> L., 1758			+		Ht	P	M
	<i>Hippodamia variegata</i> Goeze, 1777				+	Ht	P	M
	<i>Propylea quatuordecimpunctata</i> (L., 1758)				+	Ht	P	M
Oedemeridae	<i>Oedemera femorata</i> (Scopoli, 1763)			+		Ht	An	M
Mordellidae	<i>Varimorda villosa</i> (Schrank, 1781)			+		Ht	An	M
Cerambycidae	<i>Agapanthia villosoviridescens</i> (De Geer, 1775)			+		Ht	An	M

Family	Species	1	2	3	4	Ecological group according to the layer	Trophic group	Dispersal ability
Chrysomelidae	<i>Agelastica alni</i> (L., 1758)	+				T, D	Ph	W
	<i>Altica aenescens</i> (Weise, 1888)			+	+	T, D	Ph	W
	<i>Bromius obscurus</i> (L., 1758)				+	Ht	Ph	W
	<i>Cassida vibex</i> L., 1767			+		Ht	Ph	W
	<i>Crepidodera aurata</i> (Marsham, 1802)			+		T, D	Ph	W
	<i>Cryptocephalus androgyne</i> Marseul, 1875		+		+	T, D	Ph	W
	<i>Cryptocephalus octopunctatus</i> (Scopoli, 1763)			+		T, D	Ph	W
	<i>Lythraia salicariae</i> (Paykull, 1800)		+			T, D	Ph	W
	<i>Phratora vitellinae</i> (L., 1758)			+		T, D	Ph	W
	<i>Phyllotreta cruciferae</i> (Goeze, 1777)				+	T, D	Ph	W
Apionidae	<i>Plagiosterna aenea</i> (L., 1758)	+				T, D	Ph	M
	<i>Oxystoma opeticum</i> (Bach, 1854)				+	Ht	Ph	W
	<i>Brachysomus echinatus</i> (Bonsdorff, 1785)		+			Ht	Ph	W
Curculionidae	<i>Hypera miles</i> (Paykull, 1792)				+	Ht	Ph	W
	<i>Phyllobius arborator</i> (Herbst, 1797)		+	+		T, D	Ph	W
	<i>Sitona suturalis</i> Stephens, 1831				+	Ht	Ph	W
	<i>Byctiscus populi</i> (L., 1758)			+		T, D	Ph	W
Rhynchitidae	<i>Deporaus betulae</i> (L., 1758)		+	+		T, D	Ph	W
	Order Neuroptera							
Chrysopidae	<i>Chrysoperla carnea</i> (Stephens, 1836)			+	+	Ht	P	W
	<i>Chrysopa perla</i> (L., 1758)		+	+		Ht	P	W
Xiphydriidae	Order Hymenoptera							
	<i>Xiphydria camelus</i> (L., 1758)				+	D	A	M
Tenthredinidae	<i>Scolioneura betuleti</i> (Klug, 1816)		+	+	+	D	Ph	W
	<i>Tenthredo campestris</i> L., 1758			+		Ht	E	M
	<i>Tenthredo fagi</i> Panzer, 1798				+	Ht	E	M
	<i>Tenthredo mesomela</i> L., 1758			+		Ht	E	M
	<i>Tenthredo</i> sp.			+		Ht	E	M
Aulacidae	<i>Aulacus striatus</i> Jurine, 1807				+	D	An	W

Family	Species	1	2	3	4	Ecological group according to the layer	Trophic group	Dispersal ability
Ichneumonidae	<i>Glypta</i> sp. (подСемейСтНo Banchinae)				+	Ht	An	M
	подСемейСтНo Ichneumoninae			+	+	Ht	An	M
	подСемейСтНo Pimplinae				+	Ht	An	M
Chalcididae	подСемейСтНo Pteromalinae				+	Ht	An	W
	<i>Cardiopsilus productus</i> Kieffer, 1908				+	Ht	An	W
	<i>Dolichovespula saxonica</i> (Fabricius, 1793)					Ht	E	H
Proctotrupidae	<i>Eumenes pedunculatus</i> (Panzer, 1799)			+		Ht	E	H
	<i>Odynerus spinipes</i> (L., 1758)				+	Ht	E	H
	<i>Vespa crabro</i> L., 1758				+	Ht	E	H
Vespidae	<i>Vespula vulgaris</i> (L., 1758)				+	Ht	E	H
	<i>Ammophila sabulosa</i> (L., 1758)				+	H	P	H
	<i>Anoplius viaticus</i> (L., 1758)			+		H	P	H
Sphecidae	<i>Arachnospila trivialis</i> (Dahlbom, 1843)					H	P	H
	<i>Apis mellifera</i> L., 1758			+		Ht	An	H
	<i>Bombus bohemicus</i> Seidl, 1837	+	+	+	+	Ht	An	H
Pompilidae	<i>Bombus cryptarum</i> (Fabricius, 1775)	+	+	+	+	Ht	An	H
	<i>Bombus deuteronymus</i> Schulz, 1906	+			+	Ht	An	H
	<i>Bombus hortorum</i> (L., 1761)	+	+		+	Ht	An	H
Apidae	<i>Bombus hypnorum</i> (L., 1758)	+	+			Ht	An	H
	<i>Bombus jonellus</i> (Kirby, 1802)		+		+	Ht	An	H
	<i>Bombus lapidarius</i> (L., 1758)	+	+	+	+	Ht	An	H
	<i>Bombus lucorum</i> (L., 1761)	+	+	+	+	Ht	An	H
	<i>Bombus pascuorum</i> (Scopoli, 1763)	+	+	+	+	Ht	An	H
	<i>Bombus ruderarius</i> (Müller, 1776)	+			+	Ht	An	H
	<i>Bombus schrencki</i> Morawitz, 1881	+	+		+	Ht	An	H
	<i>Bombus semenoviellus</i> Skorikov, 1910	+	+	+	+	Ht	An	H
	<i>Bombus sichelii</i> Radoszkowski, 1859	+		+	+	Ht	An	H
	<i>Bombus soroeensis</i> (Fabricius, 1777)	+	+	+		Ht	An	H
	<i>Bombus sporadicus</i> Nylander, 1848	+				Ht	An	H
	<i>Bombus terrestris</i> (L., 1758)	+	+	+	+	Ht	An	H

Family	Species	Biotope	Ecological group according to the layer	Trophic group	Dispersal ability
		1 2 3 4			
Halictidae	<i>Halictus confusus</i> Blüthgen, 1926	+	Ht	An	H
	<i>Lasioglossum morio</i> (Fabricius, 1793)	+	Ht	An	H
Megachilidae	<i>Megachile versicolor</i> Smith, 1844	+	Ht	An	H
	<i>Formica cinerea</i> Mayr, 1853	+	H	E	H
	<i>Formica exsecta</i> Nylander, 1846	+	H	E	H
Formicidae	<i>Lasius niger</i> (L., 1758)	+	H	E	H
	<i>Myrmica rubra</i> (L., 1758)	+	H	E	H
	<i>Tetramorium caespitum</i> (L., 1758)	+	H	E	H
Order Diptera					
Tipulidae	<i>Tipula fascipennis</i> Meigen, 1818	+	Ht	An	M
Chaoboridae	<i>Chaoborus</i> sp.	+	Ht	An	W
	<i>Aedes communis</i> De Geer, 1776	+	Ht	Hm	W
Culicidae	<i>Culex pipiens</i> L., 1758	+	Ht	E	W
Stratiomyidae	<i>Microchrysa polita</i> (L., 1758)	+	Ht	E	M
	<i>Haematopota crassicornis</i> Wahlberg, 1848	+	Ht	E	H
Tabanidae	<i>Haematopota pluvialis</i> (L., 1758)	+	Ht	E	H
	<i>Hybomitra bimaculata</i> (Macquart, 1826)	+	Ht	E	H
	<i>Hybomitra lundbecki</i> Lyneborg, 1959	+	Ht	E	H
Asilidae	<i>Dioctria cothurnata</i> Meigen, 1820	+	Ht	P	H
Empididae	<i>Empis tessellata</i> Fabricius, 1794	+	Ht	E	M

Family	Species	1	2	3	4	Ecological group according to the layer	Trophic group	Dispersal ability
Syrphidae	<i>Eristalinus sepulchralis</i> (L., 1758)			+	+	Ht	An	H
	<i>Eristalis arbustorum</i> (L., 1758)			+	+	Ht	An	H
	<i>Eristalis pseudorupium</i> Kanervo, 1938				+	Ht	An	H
	<i>Eupeodes corollae</i> (Fabricius, 1794)			+		Ht	An	H
	<i>Helophilus pendulus</i> (L., 1758)			+		Ht	An	H
	<i>Melanostoma mellinum</i> (L., 1758)				+	Ht	An	M
	<i>Myathropa florea</i> (L., 1758)			+		Ht	An	H
	<i>Neoscia podagrica</i> (Fabricius, 1775)				+	Ht	An	M
	<i>Orthonevra intermedia</i> (Lundbeck, 1916)				+	Ht	An	M
	<i>Paragus tibialis</i> (Fallen, 1817)				+	Ht	An	M
	<i>Platycheirus</i> sp.				+	Ht	An	M
	<i>Scaeva pyrastris</i> (L., 1758)				+	Ht	An	M
	<i>Sphaerophoria scripta</i> (L., 1758)	+		+	+	Ht	An	M
	<i>Syritta pipiens</i> (L., 1758)			+	+	Ht	An	M
	<i>Syrphus ribesii</i> (L., 1758)		+	+		Ht	An	M
	<i>Syrphus vitripennis</i> Meigen, 1822			+		Ht	An	M
Agromyzidae	<i>Volucella bombylans</i> (L., 1758)				+	Ht	An	H
	<i>Volucella pellucens</i> (L., 1758)			+		Ht	An	H
	<i>Xylota segnis</i> (L., 1758)			+	+	Ht	An	M
	<i>Agromyza alnibetulae</i> Hendel, 1931			+	+	T, D	Ph	W
	<i>Eurithia anthophila</i> (Robineau-Desvoidy, 1830)		+	+		Ht	An	H
Tachinidae	? <i>Thelymyia saltuum</i> (Meigen, 1824)				+	Ht	An	H
Calliphoridae	<i>Calliphora subalpina</i> (Ringdahl, 1931)			+		T, D	E	H
Cecidomyiidae	<i>Harmandiola globuli</i> (Rubsamen, 1889)			+		Ht	Ph	W
Order Lepidoptera								
Hesperiidae	<i>Thymelicus lineola</i> (Ochsenheimer, 1808)	+			+	Ht	An	H
	<i>Colias hyale</i> (L., 1758)	+			+	Ht	An	H
Pieridae	<i>Gonepteryx rhamni</i> (L., 1758)			+	+	Ht	An	H
	<i>Pieris napi</i> (L., 1758)			+	+	Ht	An	H
	<i>Pieris rapae</i> (L., 1758)		+	+	+	Ht	An	H

Family	Species	Biotope				Ecological group according to the layer	Trophic group	Dispersal ability
		1	2	3	4			
Lycaenidae	<i>Cupido argiades</i> (Pallas, 1771)	+				Ht	An	H
	<i>Polyommatus icarus</i> (Rottemburg, 1775)	+	+	+	+	Ht	An	H
	<i>Polyommatus amandus</i> (Schneider, 1792)	+				Ht	An	H
Nymphalidae	<i>Melitaea diamina</i> (Lang, 1789)				+	Ht	An	H
	<i>Vanessa atalanta</i> (L., 1758)	+		+	+	Ht	An	H
Sphingidae	<i>Hyles galii</i> (Rottemburg, 1775)	+				Ht	An	H
Geometridae	<i>Abraxas grossulariata</i> (L., 1758)			+		Ht	An	M
	<i>Chiasmia clathrata</i> (L., 1758)			+		Ht	An	M
Notodontidae	<i>Cerura vinula</i> (L., 1758)			+		Ht	An	M
Erebidae	<i>Arctia caja</i> (L., 1758)	+				Ht	An	M

Table 3. Entomofauna composition of the pyrite cinder sludge reservoir and its immediate surroundings.

Order	Number of families	Number of species
Coleoptera	17	46
Hymenoptera	14	45
Diptera	12	35
Lepidoptera	8	15
Hemiptera	7	11
Odonata	3	5
Orthoptera	2	2
Neuroptera	1	2
Total	64	161

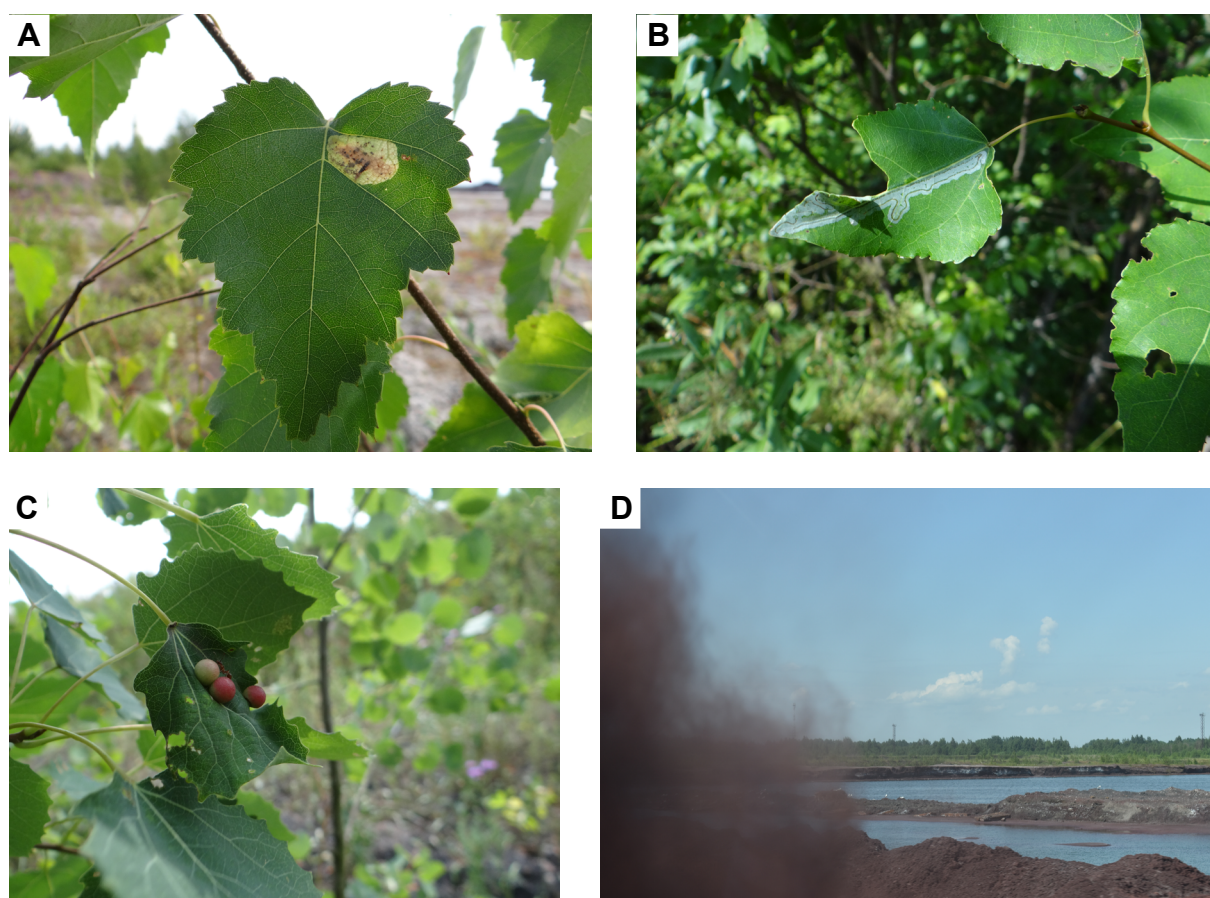


Fig. 4. Some species of phyllophagous insects found on the territory of the sludge reservoir: **A** – *Scolioneura betuleti*, larvae in sac-like mines on birch leaves; **B** – *Agromyza alnibetulae*, larvae in long ribbon-like mines on birch leaves; **C** – *Harmandiola globuli*, larvae in nut-shaped galls on aspen leaves; **D** – dust particles in the air. Photograph by Yu.N. Belova and N.S. Kolesova.

Among the tall grasses (on the upper parts of the slopes) and weeds on the tops, there are species typical of meadows and disturbed territories of the Vologda Region. So, on herbaceous plants and in the crowns of young trees, herbivorous shield bugs *Dolycoris baccarum*, *Carpocoris purpureipennis*, and spittle bugs *Philaenus spumarius*, *Lepyronia coleoptrata* are found. Phytophagous beetles colonize herbaceous plants: leaf beetles *Cassida vibex*, *Crepidodera aurata* and weevils *Sitona suturalis*, *Hypera miles*. On flowering plants with large flowers and inflorescences, there are large beetles: flower chafers *Protaetia cuprea* and *Oxythyrea funesta*, and stem-boring longhorns *Agapanthia villosa viridescens*.

On the top of the sludge reservoir and near the storage site for cinders, there are numerous adults of anthophilous insects on flowering plants. They feed on flowers with nectar and pollen and have strong dispersal abilities. These are hoverflies (19 species, the most numerous species are *Eristalis arbustorum*, *Syrirta pipiens*), bumblebees (16 species, predominated by *Bombus terrestris* and *B. lapidarius* (Fig. 6)), butterflies (6 species, *Polyommatus icarus* is the most frequently found).

On the tops and slopes of the sludge reservoir, ants are numerous, the species *Formica cinerea* and *Lasius niger* predominate. They build underground nests on dry and well-warmed peaks, as well as on the slopes.

In total, 5 species of ants were found in the study area. *Formica cinerea* was found in all the biotopes along the sludge reservoir profile, the rest of the species were registered on one or more profile sites. For the first time in the Vologda Region, *Tetramorium caespitum* was found at the foot of the sludge reservoir. Along the perimeter of the dump a rare species for the region, *Formica exsecta*, was found,

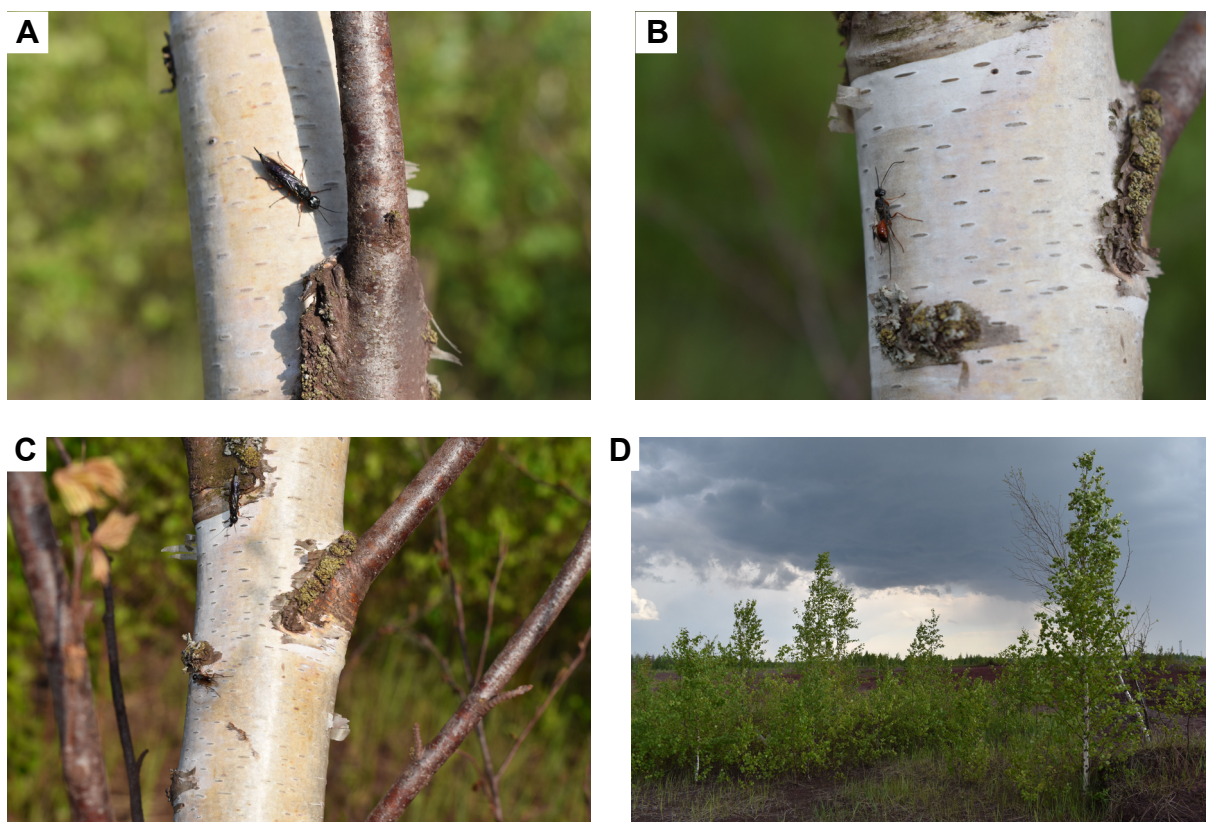


Fig. 5. Parasite and host: **A** – *Xiphidria camelus*; **B** – *Aulacus striatus*; **C** – parasite *A. striatus* in search of its host *X. camelus*; **D** – the habitat of the species on the top of the sludge reservoir. Photograph by N.S. Kolesova.

at the foot and along the slopes – *Myrmica rubra* was observed. In all the studied areas, except for the slopes, the species *Lasius niger* was found. However, the fineness of the biotopes and their close proximity suggest that all the ant species move along the profile of the sludge reservoir in search of food.

A common ecological feature of all these ant species, with the exception of *Myrmica rubra*, is that they prefer well-lit areas (sparse forests, edges, meadows) (Dunaev, 1997). *Lasius niger* can live in cities and make nests under asphalt; in addition, this species was noted as dominant in lead and zinc production dumps (Blinova, 2015), and coal dumps (Eremeeva et al., 2015a).

Adult ants feed on honeydew (sugary excrement) of aphids that suck sap on herbaceous and woody plants. Probably, it is ants that contribute to the wide distribution and high number of aphids on the sludge reservoir, as they protect their colonies from predators. In turn, the high number of aphids determines the formation of a rich food base for their specialized predators – ladybugs, some genera of hoverflies and lacewings, the larvae of which develop on the surface of plants. 4 species of ladybugs were found on the sludge reservoir: *Coccinella quinquepunctata*, *C. septempunctata*, *Hippodamia variegata*, *Propylea quatuordecimpunctata*. In mid-July, the larvae and adults of *Coccinella septempunctata*, as well as pupae and adults of *Hippodamia variegata* were the most numerous (Fig. 7). The adults of hoverflies with predatory larvae from the genera *Sphaerophoria*, *Scaeva*, *Syrphus* and *Eupeodes* were often found on flowers. 2 species of lacewings (*Chrysopa perla* and *Chrysoperla carnea*) were found in the herbaceous vegetation.

On the slopes and top of the sludge reservoir we found the adults of the species whose larvae develop in water bodies: dragonflies *Sympetrum flaveolum* and *Coenagrion hastulatum*, blood-sucking females of horseflies *Hybomitra bimaculata*, *H. lundbecki*, *Haematopota pluvialis*, *H. crassicornis*. All of them actively move in search of food.

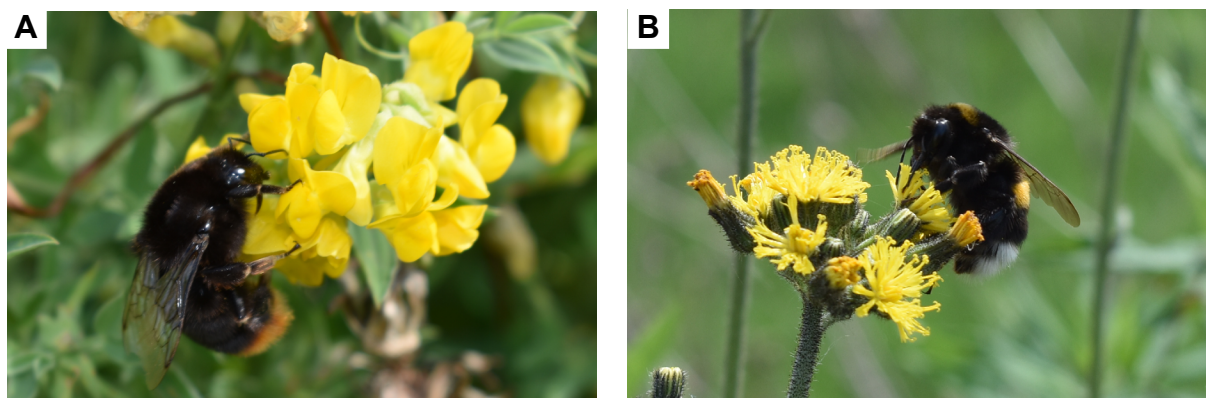


Fig. 6. Bumblebee species often found on the slopes and top of the sludge reservoir: **A** – rock bumblebee *Bombus lapidarius* on the meadow vetchling *Lathyrus pratensis* L.; **B** – ground bumblebee *B. terrestris* on hawkweed *Pilosella* sp. Photograph by N.S. Kolesova.

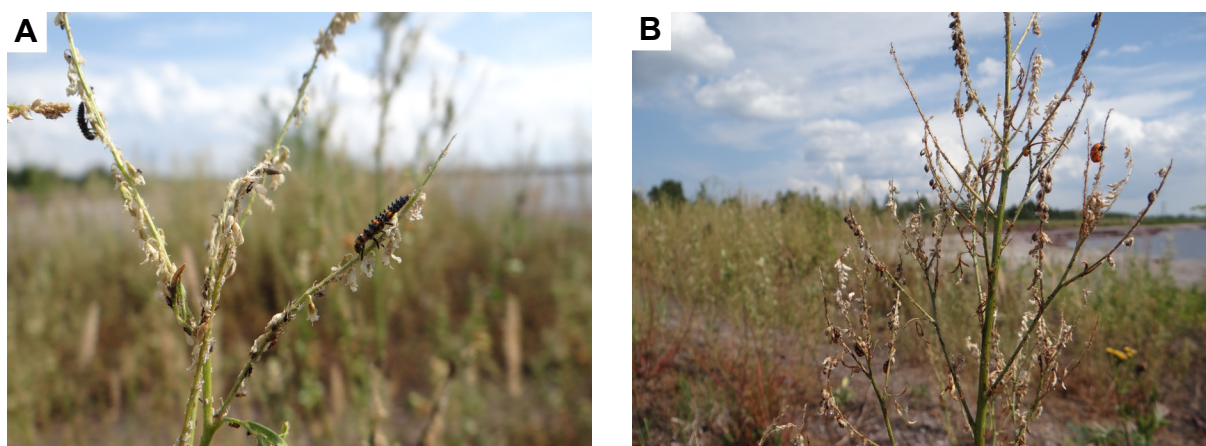


Fig. 7. Ladybugs on the top of the sludge reservoir: **A** – larvae of *Coccinella septempunctata*; **B** – pupae of *Hippodamia variegata*. Photograph by Yu.N. Belova.

The species listed in the Red Book of the Vologda Region and the list of species (taxa) in need of scientific monitoring in the region were identified on the territory of the sludge reservoir³. These are the protected pollinating insects *Bombus deuteronymus* (at the top) and *B. sporadicus* (along the perimeter) and those in need of scientific monitoring *B. jonellus* (at the foot and on the slopes), *B. sichelii* (perimeter, slopes, top) and *B. schrencki* (perimeter, foot, top).

Ecological characteristics of insect fauna

The majority of insect species recorded as adults on the sludge reservoir belong to the ecological group of mesophiles. An amphibiotic species (*Acilius canaliculatus*, Dytiscidae) was found on the top of the sludge reservoir near the pond.

³ Resolution of the Government of the Vologda Region No. 942 dated 25.07.2022 “On Approval of Lists of Rare and Endangered Species (Intraspecific Taxa) of Plants, Fungi and Animals Listed in the Red Book of the Vologda Region, lists of Species (Intraspecific Taxa) of Plants, fungi and Animals in Need of Scientific Monitoring in the Vologda Region, and on Amendments to the resolution The Government of the region dated March 29, 2004 No. 320 and the invalidation of certain resolutions of the Government of the region”.

Table 4. Ecological characteristics of the insect fauna of the sludge reservoir according to the tiered distribution of species in plant assemblages. The number before the slash specifies the number of species, the number after the slash specifies the proportion of total species, %.

Environmental group	Sludge reservoir profile part			
	Perimeter	Foot	Slopes	Top
Herpetobionts	3/7.5	8/17.8	5/6.9	6/6.9
Hortobionts	34/85.0	28/62.2	55/76.4	71/81.6
Tamno- and dendrobionts	3/7.5	9/20.0	12/16.7	10/10.3
Amphibionts	–	–	–	1/1.1
Total	40/100	45/100	72/100	87/100

Table 5. Ecological characteristics of the insect fauna of sludge reservoirs according to the trophic features of species. The number before the slash is the number of species, the number after the slash is the proportion of the total number of species, %.

Environmental group	Sludge reservoir profile part			
	Perimeter	Foot	Slopes	Top
Predatory	4/10.0	9/20.0	9/12.5	13/14.9
Anthophagous and anthophilous	25/62.5	16/35.6	36/50.0	47/54.0
Phyllophagous	6/15.0	11/24.4	17/23.6	11/12.6
Euryphagous	6/12.5	8/17.8	10/13.9	12/13.8
Aphagous	–	–	–	1/1.1
Total	40/100	45/100	72/100	87/100

Table 6. Ecological characteristics of the insect fauna of the sludge reservoir according to the dispersal ability of species. The number before the slash is the number of species, the number after the slash is the proportion the total number of species, %.

Environmental group	Sludge reservoir profile part			
	Perimeter	Foot	Slopes	Top
High dispersal ability	30/75.0	21/46.7	32/44.4	41/47.2
Moderate dispersal ability	7/17.5	9/20.0	24/33.3	29/33.3
Week dispersal ability	3/7.5	15/33.3	16/22.3	17/19.5
Total	40/100	45/100	72/100	87/100

The ecological characteristics of the insect fauna from the point of view of the tiered distribution of species in assemblages and their belonging to trophic groups naturally determine the characteristic features of the types of habitats on the sludge reservoir and its immediate surroundings (the areas with woody and herbaceous vegetation) (Tables 4–6).

Along the perimeter and at the top of the sludge reservoir, where herbaceous vegetation prevails, the proportion of hortobionts is higher, and the number of species associated with woody vegetation is lower (Table 4) compared to forest (foot) and edge (slopes) areas. At the same time, the contribution of the hortobionts to the composition of biotopic insect complexes assemblages in the direction from the foot to the top of the sludge reservoir. The proportion of the herpetobionts in the biotopes with herbaceous vegetation, regardless of the position on the sludge reservoir, remains approximately at the same level; only in forest biotopes at the foot of the reservoir it reaches higher values.

Among the herbaceous vegetation of the open areas (the perimeter and top), the proportion of species feeding on flowers (anthophagous) and pollen and nectar on flowers (anthophiles) is naturally high (Table 5). From the foot of the sludge reservoir to its top, the proportion of the species trophically associated with flowers increases, and the proportion of phylophagous species decreases. The insects of other trophic groups in the fauna of biotopes in different parts of the dump form approximately the same proportions, with the exception of the foot of the reservoir, where the proportion of the predators and the euryphagous species is slightly higher.

Due to the high proportion of hortobionts feeding on flowers (anthophagous and anthophilous), the species with highly developed and moderate dispersal abilities prevail in the biotopes on the slopes and top of the sludge reservoir, as well as along its perimeter (Table 6), since insects of this ecological group have to actively move in search of food.

Conclusion

A total of 161 species of insects from 64 families and 8 orders were found on the sludge reservoir of pyrite cinders in the vicinity of the city of Cherepovets, Vologda Region. The analysis of the collected materials shows that the diversity of the insect species composition on the sludge reservoir is significantly influenced by the intricate outline of the areas with different types of vegetation due to, the significant difference in moisture and lighting conditions, the dryness of the surface at the top and in the upper part of the slopes of the reservoir.

The entomofauna of the sludge reservoir is formed due to its colonization by species from the immediate natural environment. The insect fauna of the dump is characteristic of a marginal forest, but the assemblage of phylophagous insects developing in the crowns is rather poor. At the same time, the anthophilous insects are well represented. A contribution to the formation of the fauna is made by adults of insects (dragonflies, mosquitoes, horseflies, hoverflies, marsh beetles) developing at the larval stage in the ditches surrounding the protective dam of the sludge reservoir. At the top of the sludge reservoir, a characteristic species assemblage is formed, in which ants play an important role.

In general, the overwhelming majority of the insect species encountered are typical for natural assemblages of anthropogenically altered landscapes with a wide distribution of secondary meadows, edges and small-leaved forests.

The obtained data agree with the results of the studies of invertebrate animals on dumps of various compositions. The fauna of anthropogenic substrates consists of the species typical for natural and transformed biocenoses of the region. The species with well-developed dispersal abilities predominate. The study shows that under conditions of low humidity the specific insect assemblages are formed on the top and slopes of the pyrite cinder sludge reservoir. The thermophilic ant species building nests in soil are numerous in such complexes.

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