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ENVIRONMENTALLY REALISTIC CONCENTRATION OF MICROPLASTIC MODULATES THE EFFECT OF PHARMACEUTICAL IBUPROFEN ON THE BIVALVE MOLLUSK

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Microplastics became the internationally recognized as ubiquitous pollutants with potentially serious consequences in the environment [3]. Microplastics resulted from the utilization of plural plastics originated from the personal care products. They are also used in medical applications, e.g. in dentist tooth polish, and as carriers to deliver active pharmaceutical agents. The studies of their effects on the aquatic organisms are mostly focused on the marine organisms. It was shown the mechanistic disturbing of subcellular structures, namely lysosomes in marine mollusk species [3].

However, freshwater species that are main their living targets in the environment are investigated less. In the realistic environment microplastics are combined with the plural other contaminants. Expectedly, it can sorb these substances and change their biological activities. Nonsteroidal anti-inflammatory drugs (NSAIDs) are a group of pharmaceuticals widely and highly consumed in the market due to a low price and over-the-counter accessibility. Ibuprofen, an inhibitor of prostanoid biosynthesis, is a common NSAID used for the management of pain, inflammation and fever. NSAIDs have been detected in the environment in the range from ng/L to μg/L only, but their disruptive effects on the aquatic animals is evident. Microplastic was shown to sorb NSAIDs ibuprofen, naproxen, diclofenac, mainly ruled by hydrophobic interactions [1]. However, its function as the catalyst for the impact of pharmaceuticals is underestimated and requires a crucial examination. Filter feeders, such as bivalve mollusks, are particularly vulnerable to microplastic ingestion in wild

as they are able to feed directly on it and may even selectively ingest them. To consider the possible interaction of the confounding factors (eco-exposome approach), the history of population must be taken into account. It was shown the site-dependent differences in the oxidative stress parameters and apoptotic activities among the populations of mollusks from the areas of intense human activity and pristine sites [2].

The goal of this study was to elucidate the ability of microplastic to influence the biochemical responses of freshwater bivalve mollusk to NSAID ibuprofen in the environmentally relevant sub-chronic exposure, utilizing the oxidative sress and toxicity biomarkers. The specimens of bivalve mollusks *Unio tumidus* were collected from two populations: in pristine (Pr) and agricultural (Ag) sites. We treated mollusks with microplastic PET particles (M, 1 mg L^{-1}, obtained from the powder which was sieved with a standard mesh of size < 0.5 mm), ibuprofen of pharmaceutical quality (I, PJSC SIC Borshchahivskiy CPP, M01A E01, 0.8 μg L^{-1}), or with their combination (MI) for 14 days.

Untreated mussels from both sites (PrC and AgC) were also examined after the same time of being in the laboratory tanks. The antioxidant activity was assessed from the Mn- and Cu,Zn-superoxide dismutases (Mn- and Cu,Zn-SOD) and catalase (CAT) activities, levels of the products of lipid peroxidation (TBARS) and protein carbonyls (PCs). The cytotoxicity was estimated from the cholinesterase (ChE) and lysosomal membrane stability (Neutral Red Retention (NRR) assay).

We have found significantly different manifestations of control groups of mussels collected at a relatively unpolluted site (PrC-group) as compared with those collected at a contaminated site (AgC-group) for indicators of oxidative stress, even after being kept for 21 days in laboratory conditions. Particularly, the residents of two populations were distinguished by substantially stronger antioxidant defense. In the digestive gland of the mollusks from pristine site, the activities of the Mn-SOD, Cu,Zn-SOD, catalase were by 4.7, 1.2, 1.7 times higher correspondingly, and the concentrations of TBARS and PCs were by 1.3 and 1.5 times lower correspondingly.

The level of the soluble protein was higher in the 1.3 times in the PrC-group. Importantly, the ChE activity was lower 1.3 times in

the AgC group indicating the severe neurotoxicity of the environment. Hence, the mollusks from the Ag site were more subjected to stress due to weak antioxidant activities, high level of oxidative destruction and presence of neurotoxic substances. Expectedly, they were less able to adapt to the additional adverse effects. However, the NRR values were similar in both control groups confirming the absence of the severe site-related toxic impacts.

The exposures affected the activities of antioxidant enzymes similarly in the representatives of both populations. The redistribution of SOD activities was shown with the elevation of Mn-SOD and decrease of Cu,Zn-SOD activities under the effect of M. It was reveled under the combine exposure (MI-group). Similarly, the increase of catalase activity was indicated specifically in the MI –groups from both populations. The significant increase of TBARS level under the exposure to M and MI was indicated only in the Ag-groups. Only the responses of PCs to exposures were different in two populations. Precisely, in the PrMI- and PrI-groups, the PCs level was increased, whereas in the AgMI- and AgI-groups it was decreased compared to corresponding control value. The changes of the soluble protein level were similar but less prominent.

The ChE activity was sensitive to the ibuprofen demonstrating the significant increase in the PrMI- and AgI-groups. At that, the results did not detect the oppression of ChE activity in all experimental groups indicating the absence of severe toxicity. The NRR test has shown the selective differences only depending on the ibuprofen presence and only in the AgI-group. Consequently, this effect was specific to the ibuprofen but was revealed only in the group subjected to the complex pressure of ibuprofen and chronic environmental pressure.

According to the Principal Component Analysis (PCA), the negative intercorrelation of Mn-SOD and CAT from the one side and TBARS from another side against the Axis 1 was the most important regularity in the determining of the oxidative stress response. The NRR index was separated independently against the Axis 2 of the PCA plot.

Discriminant analysis loaded all studied groups from the Ag population with the highly distinct group centroids and located separately PrI, PrM and jointly PrC and PrMI from the Pr population.

In both populations, the combine exposed group loaded the middle position between I and M groups, indicating the interconnection of microplastics and ibuprofen effects.

Collectively, this study suggested that the microplastic leveled the particular effects of ibuprofen but induce the oxidative stress in the sub-chronic environmentally realistic exposures of the freshwater molluscs. However, the specimens from the polluted site were more vulnerable in all exposures. These results confirm the valuability of the utilized model to understand the earlier effects of microplastic in the combine environmental exposure, and the importance of the initial resistance of the organism depending on its history of population.

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МІЖПРЕДМЕТНІ ЗВ'ЯЗКИ ХІМІЇ, БІОЛОГІЇ ТА ФІЗИКИ ПІД ЧАС ВИВЧЕННЯ ІНТЕГРОВАНОГО КУРСУ «ПРИРОДОЗНАВСТВО» В СТАРШІЙ ШКОЛІ

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Відповідно до мети середньої загальноосвітньої школи вивчення природничих дисциплін в інтегрованому курсі «Природознавство», має забезпечувати знання учнями фундаментальних законів природи, формування наукового світогляду учнів і сучасної природничо-наукової картини світу, розуміння глобальних проблем сучасності та комплексного підходу до їх розв'язання, ціннісного ставлення до природи, стратегії поведінки людини в біосфері.

Проблема міжпредметних зв'язків не нова і досліджувалась багатьма дидактами та методистами. Суть міжпредметних зв'язків, їх функції та види розкриваються у дослідженнях Борисенка Н. Ф., Сорокіна Н. А. , Вороніної Л. П., Мальованого Ю. І. та інших авторів.

Незважаючи на зростаючий інтерес вчених до проблеми реалізації міжпредметних зв'язків у навчанні хімії, біології та фізики, істотні питання формування в учнів міжпредметних знань ще не розв'язані. Зокрема, не визначені критерії відбору міжпредметних відомостей до конкретного уроку, необхідних для усвідомленого засвоєння учнями знань природознавства.

Завданнями нашого дослідження було: 1) виявити умови, що забезпечують ефективну реалізацію міжпредметних зв'язків у навчанні хімії, біології та фізики; 2) визначити принципи та критерії відбору міжпредметного матеріалу; 3) розробити методику реалізації міжпредметних зв'язків на уроках природознавства в старшій школі.

В наш час одні дослідники розглядають міжпредметні зв'язки як дидактичний еквівалент зв'язків міжнаукових, що виникають у процесі взаємодії наук при вивченні явищ природи й