ГІГІЄНА І ОРГАНІЗАЦІЯ ОХОРОНИ ЗДОРОВ'Я

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Spirulina in the rehabilitation of children with elevated blood lead concentration

Introduction. According to literary data, almost one in three children in the world has a blood lead concentration (BLC) of more than 5μg/dL. This value is the threshold for initiating clinical intervention according to WHO recommendations. At this BLC threshold (referred to as the 'public health intervention concentration') public health action is recommended in the USA, Australia, France, England. In Ukraine, there are no programs of this scale yet. Scientific work in this direction is rare.

The aim of the study was to evaluate the effectiveness of spirulina in improving the metabolic status in Ukrainian children with elevated BLC.

Materials and methods. 33 random children aged 7 to 15 years were examined. The lead content in venous blood was detected by atomic absorption spectrometry with electrothermal atomization. Indicators of morphological and biochemical blood tests were determined by generally accepted methods.

Results. About 30% of the children had BLC ≥ 5μg/dL. They had a lower content of hemoglobin and red blood cells, activation of lipid peroxidation processes and a decrease in antioxidant protection reserves compared to children with lower BLCs. According to the WHO recommendations, the children with BLC ≥ 5μg/dL underwent nutritional intervention. As a nutritional supplement, spirulina was used according to the scheme: the first 10 days – 0.5 g 2 times a day, then 1 g 2 times a day for another 20 days. As a result, BLC significantly decreased from 7.56±0.20 to 6.26±0.57 μg/dL, hemoglobin increased from 126.91±2.15 to 137.46±1.46g/L, blood red cells increased from 4.02±0.07 to 4.39±0.05 T/L. The content of diene conjugants decreased from 20.46±1.71 to 13.82±1.27 μmol/L, and the number of sulfhydryl groups increased from 0.93±0.15 to 1.40±0.11μmol/L. The thiol-disulfide ratio increased 1.7 times.

Conclusions. Spirulina contributes to the removal of lead from the body and helps to improve the metabolic status in children with elevated BLC. This allows us to recommend this dietary supplement for the rehabilitation of children undergoing environmental lead pressure.

Key words: ecology, public health, lead, children, hemoglobin, lipid peroxidation, antioxidant protection, spirulina.

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Спіруліна в оздоровленні дітей з підвищеним рівнем свинцю в крові

Вступ. Згідно літературних даних, майже кожна третя дитина в світі має концентрацію свинцю в крові (blood lead concentration – BLC) понад 5мкг/дл. Ця величина є пороговою для початку клінічного втручання згідно рекомендацій ВООЗ. Саме при такому порозі BLC (який називають «концентрацією втручання в охорону здоров'я») у США, Австралії, Франції, Англії рекомендуються заходи громадської охорони здоров'я. В Україні програм такого масштабу ще нема. Наукові роботи в даному напрямку поодинокі.

Мета дослідження – оцінити ефективність спіруліни в покращенні метаболічного статусу в українських дітей з підвищеним рівнем свинцю в крові.

Матеріали та методи. Обстежено 33 дитини випадкової вибірки віком від 7 до 15 років. Вміст свинцю у венозній крові виявляли методом атомно-абсорбційної спектрометрії з електротермічною атомізацією. Показники морфологічного та біохімічного дослідження крові визначали за загальноприйнятими методиками.

Результати. Близько 30% обстежених дітей мали BLC ≥ 5 мкг/дл. У них був виявлений більш низький вміст гемоглобіну та еритроцитів крові, активація процесів перекисного окислення ліпідів і зниження резервів антиоксидантного захисту порівняно з дітьми з більш низькими BLC. Згідно рекомендацій ВООЗ, дітям основної групи проводили нутрітивне втручання. В якості харчової добавки для такого втручання застосовувалась спіруліна за схемою: перші 10 днів – по 0,5 г 2 рази на день, далі по 1 г 2 рази на день ще 20 днів. У результаті достовірно знизилась BLC (від 7,56±0,20 до 6,26±0,57мкг/дл), підвищився рівень гемоглобіну (від 126,91±2,15 до 137,46±1,46г/л), еритроцитів крові (від 4,02±0,07 до 4,39±0,05Т/л). Вміст дієнових кон'югатів знизився з 20,46±1,71 до 13,82±1,27 мкмоль/л, а кількість сульфгідрильних груп збільшилась від 0,93±0,15 до 1,40±0,11мкмоль/л. Тіол-дисульфідне співвідношення збільшилося в 1,7 разу.

Висновки. Спіруліна сприяє виведенню свинцю з організму, а також покращує метаболічний статус у дітей з підвищеним рівнем свинцю в крові. Це дозволяє рекомендувати дану біологічно активну добавку до їжі для оздоровлення дітей, що зазнають екологічного свинцевого пресингу.

Ключові слова: екологія, громадське здоров'я, свинець, діти, гемоглобін, перекисне окислення ліпідів, антиоксидантний захист, спіруліна.

Introduction. Lead (Pb) has been used for thousands of years in different anthropogenic activities thanks to its unique properties that allow for many applications [1]. But non-biodegradable character and continuous use results in accumulation of lead concentration in the environment and causes various ill effects [2]. Therefore, lead exposure has been a serious ecology and public health problem throughout the world over the years. The major sources of lead in the past were lead-containing paint and leaded gasoline before they were phased out due to its toxicity. Meanwhile, people continue to be exposed to lead from time to time through many other sources such as water, food, soil and air [3; 4]. Researchers believe that soil, buildings, dust and even trees constitute huge lead repositories throughout urban areas [5]. Lead exposure from these sources could have detrimental effects on human health, especially in children [1-5]. The problem is exacerbated by the fact that these patients can be challenging to identify due to their non-specific presentation and frequent lack of known exposure [6]. So most importantly, a high index of suspicion is needed since there may be no symptoms or overt clinical signs in those with mild disease [4]. But they already have shifts at the biochemical and cellular level, which can later be realized into a clear clinical picture of lead intoxication [7], such as neurotoxicity, change in psychological and behavioural development etc. [2]. To break this chain of negative changes, in the initial stages it is enough to correct the metabolic status in the body. If a raised blood lead concentration (BLC) is found, abatement of the source of exposure is the most important intervention, as chelation is usually only indicated for very high levels [4; 8]. The use of enterosorbents – materials which can be administered orally and eliminate toxic substances from the gastrointestinal tract by sorption – offers an attractive complementary protection of humans against acute and chronic poisoning [9]. For quite a long time, the attention of researchers has been attracted by spirulina. It's a microalga that has the potential for adsorption, bioaccumulation, and biodegradation of heavy metals. The microalgal strains can mitigate the hazardous chemicals via their diverse cellular mechanisms [10]. Therefore, spirulina is proposed for use in bioremediation which is the most effective technique in the revival of the environment, and it is environmentally friendly and cost-effective [2, 10]. Spirulina showed lead removal efficiency as 74% [2]. Spirulina is becoming increasingly used in health care [11].

The purpose of the work was to evaluate the effectiveness of spirulina in improving the metabolic status in Ukrainian children with elevated BLC.

Methodology/Methods. 33 children of a random sample aged 7 to 15 years who were in a paediatric medical institution were examined. The inclusion of children in the study was carried out subject to the informed consent of the parents of the children after providing detailed information about the procedure and purpose of the work. To diagnose, predict the course and evaluate the effectiveness of clinical interventions, we chose those indicators of laboratory examination that could be the most informative and at the same time relatively accessible. According to modern literature data, these are the BLC [8], indicators of anaemia [12], biomarkers of oxidative stress [13].

The determination of lead was carried out in heparinized venous blood by atomic absorption spectrometry with electrothermal atomization. General clinical tests of blood and urine were carried out according to generally accepted methods. A biochemical blood test included separate indicators of the state of the liver to assess the possible negative effects of lead on these parameters, as well as to control the safety of therapy, as shown in the literature. The content of beta-lipoproteins, bilirubin, total protein, activity of the organ-specific enzyme of the liver – alanine aminotransferase (ALT), an indicator of the thymol test was determined. The activity of lipid peroxidation (POL) processes was judged by the accumulation of primary (diene conjugants – DC) and final (malonic dialdehyde – MDA) lipoperoxidation products in the blood. The state of the antioxidant system was assessed by the activity of glutathione-peroxidase (GPO) and by the content of sulfhydryl and thiol-disulfide groups of blood proteins. The research was conducted according to unified methods. The ratio of group averages SH/SS was also calculated.

Statistical processing of the obtained data was carried out by methods of variational statistics using the Student-Fischer T-criterion.

To establish the dependence of the studied parameters on the BLC, as well as considering the recommendations of the WHO on the feasibility of clinical intervention [8], children were divided into 2 groups: 1) a group with a lead content of up to 4.9 μg/dL, n = 22; 2) a group with a lead level in the range of 5.0-9.9 μg/dL, n = 11. The control in assessing the ecopathogenic effects of lead was the first group of children. When assessing the effectiveness of the intervention, the indicators were compared on beginning and end of observation.

Evaluation of calculations χ^2 showed that by age, by the presence of certain diseases, the groups were homogeneous, so the differences in the indicators of morphological and biochemical studies could be explained in this case only by different levels of lead in the blood.

Results and Discussion. The results of the study are presented in the table 1.

Table 1

Indicators of morphological and biochemical examination of blood in children of different groups, M±m

Indicators	At the beginning of the observation		At the end of the observation	
	BLC ≤ 4.9 μg/dL	BLC 5.0–9.9 μg/dL	BLC ≤ 4.9 μg/dL	BLC 5.0–9.9 μg/dL
Lead, μg/dL	3.20±0.22	7.56±0.20*	3.57±0.41	6.26±0.57**
Hemoglobin, g/l	134.32±1.85	126.91±2.15*	134.14±1.77	137.46±1.46**
Erythrocytes, T/l	4.30±0.07	4.02±0.07*	4.28±0.05	4.39±0.05**
Eosinophils, %	2.68±0.38	4.64±0.96*	3.18±0.54	3.00±0.93
ALT, μmol/l/s	0.39±0.01	0.39±0.02	0.39±0.01	0.40±0.02
DC, μmol/l	16.36±1.21	20.46±1.71	17.14±1.32	13.82±1.27**
MDA, μmol/l	134.50±8.81	144.46±11.92	131.62±9.04	121.73±9.71
GPO, μmol/l/sec	14.90±0.77	11.84±1.75	11.40±0.84**	15.21±1.11
SH-groups, μmol/l	0.60±0.07	0.93±0.15*	0.93±0.12**	1.40±0.11**
S-S-links, μmol/l	0.20±0.03	0.36±0.09*	0.29±0.05	0.32±0.04
SH/SS index	2.94	2.55	3.19	4.32

Note. * – The difference is reliable ($p < 0.05$) with the indicator of the first group, ** – the difference is reliable ($p < 0.05$) between the indicators at the beginning and at the end of the observation in each group.

In the biochemical indicators of the functional state of the liver, there were no significant differences both between groups of children with different levels of lead and between different periods of observation, so they were not included in the table.

Analysis of BLC in children showed that about 30% of them have a concentration above 5 μg/dL at the start of observation. This concentration is a practical value at which clinical interventions can be started according to the WHO recommendations [8]. The proportion of such children in the above sample coincides with modern data. The report produced by UNICEF and Pure Earth notes that according to ground-breaking new analysis and research, around 1 in 3 children globally have blood lead levels at or above 5 μg/dL [14].

Analysis of red blood counts indicates that clinical intervention in children of the second group was justified. Thus, these children had significantly lower levels of haemoglobin and red blood cells than children of the first group. This is consistent with current research. For example, investigators searched PubMed, Scopus, and Web of Science databases for studies published between January 2010 and April 2022. They found evidence of a negative relationship between lead concentration and haemoglobin in 38 publications [12].

In children of the second group, a significantly higher relative number of eosinophils was also found 1.7 times higher than in children of the first group. This indicates a possible allergy of the body with an increase in the level of lead in the blood.

The content of diene conjugants had a pronounced tendency to increase by almost 25% in children of the second group. This indicates the activation of lipoperoxidation processes with an increase in the level of lead in the blood.

At the same time, the activity of the antioxidant protection enzyme – GPO – on the contrary, tended to decrease by 25%. This indicates a depletion of the antioxidant protection of the child's body while increasing the concentration of lead. Changes in the thiol-disulfide system in children of the second group even reached a degree of reliability. The values of both indicators of this system increased, but the increase in the number of SH groups (1.6 times) lagged the increase in the number of S-S bonds (1.8 times). As a result, the SH/SS ratio decreased (in the first group 2.94, and in the second – 2.55), which also indicates a decrease in the reserves of antioxidant protection of the child's body with an increase in the concentration of lead. It is known that violation of prooxidant-antioxidant homeostasis may be the primary mechanism associated with lead toxicity [13]. Therefore, it is important to apply medical intervention to this link of pathogenesis to prevent the development of lead-induced pathology.

When choosing a medical intervention, we relied on the recommendations of the WHO [8]. We informed the parents of the children that «the single most important action in the management of any lead exposure is to take measures to stop the exposure as quickly as possible. This alone will itself result in a reduction in the blood lead concentration and clinical improvement» [8].

According to the algorithm from the WHO, nutritional interventions are recommended in children with a BLC ≥ 5 μg/dL but < 45 μg/dL [8]. In our study, these are the levels of the second group of children. As a nutritional supplement for these children, spirulina was used 0.5 g 2 times a day for 10 days, then 1 g 2 times a day for another 20 days.

As a result of the use of spirulina in children, their BLC has significantly decreased (see Table 1). This confirms the data on the sorption properties of spirulina [2; 10].

At the same time, those studied indicators that at the beginning of the observation had differences with control were also subjected to correction. At the end of the observation, children of the second group significantly increased the concentration of haemoglobin and the content of red blood cells. The relative number of eosinophils decreased by 1.5 times. The level of diene conjugants has significantly decreased, the number of sulfhydryl groups of blood proteins has increased, the thiol-disulfide ratio has increased 1.7 times.

The positive effects of spirulina can be explained by its composition. It contains vitamins of the antioxidant group (A, C and E). It is also a storehouse of many essential minerals, including iron [15]. The data obtained by us are consistent with studies that have proven the promising effects of spirulina in the prevention and treatment of anaemia, oxidative stress and other pathological conditions [11; 15].

Children tolerated nutritional intervention well. Its safety was also indicated by the absence of changes in the activity of ALT and other indicators of the functional state of the liver.

Conclusions.

1. Spirulina showed enterosorbing properties, contributed to the removal of lead from the body.
2. This nutritional supplement has also helped improve metabolic status in children with elevated blood lead levels.
3. This allows us to recommend spirulina for the rehabilitation of children undergoing environmental lead pressure.
4. However, more studies are needed.

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