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Heavy Metals and Radioactivity in Phosphate Fertilizers: Short Term Detrimental Effects.

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Les métaux lourds sont le groupe d'éléments chimiques dont la densité dépasse 5 g/cm^3. Cependant, cette définition a été tirée de la littérature technique. Pour la classification biologique, il est plus correcte d'être guidé non par la densité mais par une masse atomique, c'est à dire de compter comme métaux lourds tous les métaux avec une masse relative de plus de 40.

On dit que les métaux lourds ne sont pas toujours toxiques. Cette conception est erronée car dans ce groupe il y a le cuivre, le zinc, le molybdène, le cobalt, le manganèse, le fer, autant d'éléments ayant une grande signification biologique positive démontrée et prouvée de longue date. Certains ont été appelés "oligo-éléments" parce qu'ils se rencontrent en concentrations dans lesquelles ils sont utiles et nécessaires aux organismes vivants. Ainsi les micro-éléments et les métaux lourds sont de la même notion, mais utilisés dans différents cas, décrivant leur concentration dans le sol, les engrais et la production agricole. Il serait plus correcte d'employer le terme "métal lourd" en parlant de concentration dangereuse d'éléments avec une masse atomique relative de plus de 40, et de parler de "micro-éléments", dans ce cas, quand il est dans un sol, des plantes, des animaux, et l'organisme humain en concentration non toxique ou bien il est utilisé en petites quantités comme engrais ou additifs minéraux pour l'amélioration des conditions de croissance, de développement des plantes ou des animaux. (1)

Toutefois, il existe un groupe de métaux qui n'ont recueilli qu'une définition négative, l'appellation de "lourd" voulant dire toxique, en raison de leur aptitude à s'accumuler dans les produits alimentaires. Il n'y en a pas tant que cela, seulement environ une douzaine caractérisés par leur effet sur l'environnement. Parmi eux se trouvent le mercure, le plomb, le cadmium, l'arsenic, le cuivre, le vanadium, l'étain, le zinc, l'antimoine, le molybdène, le cobalt, le nickel. (2) Parmi les plus toxiques, il y a : le mercure, le cadmium, le plomb et l'arsenic.

Heavy metals are placed in a group of chemical elements whose density is more than 5 gm/cm^3. However such a definition was adopted from technical literature. For biological classification it is more correct to be guided not by the density, but by the atomic mass, that is, all metals with relative mass of more than 40.

It is generally considered that heavy metals are always toxic. Such conception is mistaken, because in this group: copper, zinc, molybdenum, cobalt, manganese, iron, all display positive biological activities proven a long time ago. Some of them were called “microelements” because under low concentrations they are useful and necessary to living organisms. So, microelements and heavy metals have similarities but become different depending on their concentration in soil, fertilizers and agricultural produce. It would be more correct to use the term “heavy metal" when referring to the dangerous element concentrations for animal organisms with its relative atomic mass more than 40, and to “microelement” in soil, plants, animals and human organism in non-toxic concentrations or when it is used in small amounts as fertilizer or mineral food additives for improvement of growth conditions, development of plants and animals[1].

However there is a group of “heavy” metals, which is deleteriously “toxic", because of their ability to be accumulated in food products. They are not so many, only about dozen, which are acknowledged as main pollutants of the environment. Among them are: mercury, lead, cadmium, arsenic, copper, vanadium, tin, zinc, antimony, molybdenum, cobalt, and nickel[2]. The most toxic are mercury, cadmium, lead and arsenic.

Heavy metals enter the environment by two means: natural and technogeneous. From the natural sources the most significant are: weathering of minerals, erosion, and volcanic activity. From the technogeneous sources are : extraction and processing of minerals, incineration of fuel. The latter is a major source of heavy metals in soil [2]. Besides, comparative estimates of the heavy metals intensity in the environment from different sources show, that 60 per cent of many of the elements of technogeneous origin are not involved in the natural biological rotation. The soil accumulation of cadmium, strontium, uranium, thorium and radium can be related to application of phosphoric fertilizers. Strontium is added to the soil through single superphosphate and calcium sulphate (phosphogypsum), produced from the Russian Apatit. Cadmium appears in soil in rural economy through application of phosphates and mineral fertilizers. The population growth and its attendant welfare meant intensification of agricultural production, which in turn requires increased application of mineral fertilizers including phosphates as well[3]. Therefore, this brings a very significant question of setting the rate for permissible level of heavy metals in raw materials, mineral fertilizers and agricultural produce. In France, for example, mineral fertilizers must be analyzed for their contents of heavy metals as Cd, Mg, Pb, Cr, Ni, Se, Zn, As, and Mo, so that they do not exceed the limitations upon their application. In Netherlands all producers and importers of mineral fertilizers must make quarterly report regarding the content of cadmium in their production. In Belgium, the content of Cd in fertilizers must not exceed 90 mg/kg P_2O_5, in Denmark - 48 mg/kg P_2O_5, in Germany - 90 mg/kg P_2O_5, in Norway and Sweden - 44 mg/kg P_2O_5, and in Switzerland - 22 mg/kg P_2O_5. EFMA (European Fertilizer Manufacturers Association) recommended to the European Commission to limit cadmium level for phosphatic fertilizers produced in EC to 60 mg/kg P_2O_5 [4].

In Ukraine, the specialists at the Ukraine Ministry of Health Protection, after studying the problem, came to the conclusion of the necessity to set a rate allowable for heavy metals in raw materials, from Apatit and other phosphate rocks. The limitations were adopted on imported phosphates with high content of heavy metals and radio-activity delivered from the North African, Near and Middle East countries, because Ukrainian phosphate source of raw materials has not yet been exploited. In this connection the following rates were brought into action for phosphate rock: the content of cadmium must not exceed 12 mg/kg, of lead - not more than 20 mg/kg, of arsenic - not more than 10 mg/kg[5], and the total effective radionuclid activity must not exceed 1860 BCU/kg.

As far as the Russian, North African, Near and Middle East deposits are concerned the content of heavy metals and total effective radionuclid activity are different, and the Ukrainian specialists have made researches on sample analysis from the various deposits. The data of the contents of heavy metals and level of total effective radionuclid activity in phosphate raw materials are given in Table 1.

Since the phosphates (phosphate rock and Apatit rock) are the raw materials in production of mineral fertilizers containing P_2O_5, the heavy metals are natural addition in phosphatic fertilizers (ammonium phosphates, NP, DAP, all kinds of superphosphate, etc.).

According to H. Schroeder and J. Balassa, the American single superphosphate is a source of cadmium. Among elements contained in the American single superphosphate, J.Caro listed such heavy metals as chromium, cobalt, copper, lead, nickel, vanadium and zinc[1]. In Austria about 160t. of cadmium have been added to the soil through superphosphate.[1].

Along with heavy metals in raw materials with phosphatic fertilizers there are radio-active elements with enormous half-decay period of 5-10 billion years. First of all there are uranium-238 and thorium-232. It is known, that after 80 years of application of phosphatic fertilizers in some USA states the uranium-238 concentration in soils has doubled. Similar problem has taken place in Germany, where the level of natural radio-active uranium elements and radium in cultivated soils is 6 to 9 % above the uncultivated[1].

Since Ukraine currently does not have a national phosphate raw materials industry, and traditional raw materials from Russia (Kola phosphates) being offered at high prices and become inaccessible to national producers, the branch enterprises are feeling “raw material hunger". In this connection the branch enterprises of phosphatic mineral fertilizers have turned their eyes to the North African, Near and Middle East countries in search for alternative raw material sources[6]. Today the Ukrainian enterprises in Sumy and Dneprodzerzhynsk had processed potential parties’ phosphate rocks from Algeria, Tunisia and Syria. As a result they produced ammonium phosphate, monoammonium phosphate, diammonium phosphate, granfos (0:29:0), and others. Recently negotiations with producers of phosphate rock, including Egypt, Jordan, Israel and others have been initiated.

The task ahead for the Ukrainian producers of mineral fertilizers is clear: to provide Ukraine with the necessary amount of agricultural input of mineral fertilizers, including phosphates and to guarantee a healthy ecological system, without which any abundance in agricultural production will not bring the desired results. Naturally, the organization of transportation, storage and processing raw materials from North Africa, and application of fertilizers on their arable land with phosphate rock, require special analysis, including an ecological one[7]. It would not be feasible to analyse all grades of phosphate rocks from North Africa and other countries because of numerous mines there. We shall limit this paper to the analysis of Algerian phosphate rock of the “Djebel Onk" deposit and the Tunisian phosphate rock of “Gafsa” deposit and the fertilizers produced from these raw materials since they are already marketed to Ukraine enterprises. Besides, the quality of North African phosphate rock, their chemical composition are quite similar, in spite of their diverse deposits. Let us consider the most toxic of the heavy metals such as Sr, Cd, Pb, and As. And note that the last three elements are subject regulation on permissible limits in Ukraine.

Strontium.

The level of this highly toxic element in North African phosphate rock is quite insignificant (Table 1). In the phosphate rock from Tunisia the level of strontium is 0,41 %, and in the Algerian - from 0,18% to 0,28%. The total strontium content in Kola Apatit is 3,0%. According to the analyses, in single superphosphate derived from the Kola Apatit the strontium oxide is approximately 1 to 1,2%. For this reason in the Ukrainian soils, after more than 10 years of fertilization with tons of strontium, its level has increased between 1991-1994 [7, 10]. At these strontium levels they pose dangers for animals and human beings. In this case the North African phosphate rock has obvious advantage in comparison with Russian Apatit.

Table 1 : Contents of heavy metals and level of natural radio-activity in phosphatic raw materials from different deposits.

Index Name	Syria	Israel	Algeria	Tunisia	Marocco	Jordan	Republic of South Africa	Uganda	Egypt	Russia, Phosphate Rock from Briansk	Russia, Kola Apatit
Sr, %	0.19	0.012-0.27	0.18-0.28	0.41	-	0.11-0.22	0.46	0.49	-	-	3.0
Mn, mg/kg	6-6.5	7-440	17-30	33	-	9-285	138	1350	1225	-	26.0
Co, mg/kg	8	10	11	4.7	-	8.5-12	10	90	17	-	4.0
Ni, mg/kg	53.5-60.5	61-80	28	15	-	20-71	10	100	20	-	15.4
Zn, mg/kg	320-340	29-630	88-150	22-120	-	85-420	11	290	190	30	25.0
Cd, mg/kg	8-15	1.5-32.4	10-16.2	21	17	2.7-34.7	-	0.25	2.6	1	1
Hg, mg/kg	-	0.002	0.004								0.004
Cu, mg/kg	5-29	8-31.3	10-16	11	-	9-27	118	33	10	-	15.0
Pb, mg/kg	2-3.5	2.3-5.8	1.1-2.7	1.7-2.0	1	1-2.3	15.4	9	33	1.5	1.8
As, mg/kg	2.1-10.5	-	8	5.7	-	2.6-27.5	8.7	-	17.3	3.4	2
Natural radio-activity* BCU/kg	518.2		670+/-141	442.4		712.6			335		

* - Determines by summary effective radionuclid activity ^{238}U, ^{232}Th, ^{40}K

Cadmium.

The highest concentration of this element is found in phosphate rock from Tunisia, with level of 21mg/kg. In the phosphate rock from Algeria the concentration reaches 16 mg/kg, but most analyses showed that the level did not exceed 12 mg/kg according to the Ukraine Ministry of Health Protection, and only 20 to 40% of it is in water-soluble form. From this analyses the North African phosphate rock is considerably different from the Russian raw materials. Cadmium compounds under dissolved conditions possess mutagenic and carcinogenic properties[9]. Maximum permissible daily cadmium dose for adults must not exceed 1.2 mg per kg of body mass. When applying 100kg P_2O_5 with monoammonium phosphate with phosphate derived from North African phosphate rock per hectare of tillage, the concentration of cadmium can increase by 0.1 mg/kg. In this connection although it has a little presence in phosphate rock, it is expedient to exclude it from fertilizer solutions[7]. For example, it is technologically feasible to use sulphates instead.[8].

Lead.

This chemical element is most commonly present in Egyptian phosphate rock of the “Abu Tartur” deposit. All the rest of the deposits do not contain more than 10 mg/kg. In the Algerian phosphate rock the lead level is about 3 mg/kg, and in the Tunisian - 2 mg/kg. The safe daily dosage for human is 7mg/kg of body mass[7]. The increase in daily dosage results in general intoxication, damaged liver function and the arrest of cardiac activity. However the amount of lead that enters the environment through the mineral fertilizers is small because 100kg of P_2O_5 per hectare of soils deposit only 1-2 gm. of lead, while the atmospheric precipitations deposit up to 30 gm per hectare.

Arsenic.

The concentration of arsenic in the Algerian phosphate rock does exceed than 8mg/kg, in the Tunisian - about 6mg/kg and only in the Egyptian phosphate rock its level exceed 17mg/kg. Arsenic compounds are toxic for plants when accumulated in tissues at levels of 5-20mg/kg of the dry mass. A preliminary analysis indicates that with the phosphates derived from the North African rock, per hectare of tillage will gain about 0.1 gm. of arsenic[7]. Therefore its concentration in soils can increase about 0.04 mg/kg annually. It is necessary to note that other sources of arsenic in soil include pesticides, fumigants and herbicides. So, arsenic presence in very small quantities in North African, Near and Middle East phosphate rocks would not cause basic ecological detriment.

From the analysis of North African phosphate rock chemical composition, it is clear that the most toxic elements when used by the illiterate and untrained farmers in agrochemical application of phosphatic fertilizers can lead to ecological anomalies.

Before approving its use in agriculture, phosphatic fertilizers produced from North African, Near and Middle East phosphate rock, must undergo toxicological medical-biological researches by the Institute of Ministry of Ukraine Health Protection. These included superphosphates of different grades, acid decomposition of phosphate raw materials and granfoses of diverse grades, obtained by mechanical mixing of ground phosphate rock with plasficizer and further granulation of mixtures. Table 1 shows the chemical composition of heavy metals in these fertilizers. Table 2 shows the chemical composition of heavy metals in ammonium phosphate, obtained by acid decomposition of phosphate rock from Tunisia “Gafsa” deposit and also monoammonium phosphate and diammonium phosphate, obtained by ammoniated phosphoric acid on the phosphate rock from Tunisia. The resultant products similarly underwent through research analysis by institutions of the Ukraine Ministry of Health Protection.

The toxicology of these fertilizers was studied using white rats, mice, guinea-pigs and crawling creatures in accordance with requirements of toxic research as stated in "Toxicometry of chemical matters contaminating environment". UN Program on Environment. As a result of these researches it was found, that all mineral fertilizers made from the Algerian phosphate rock are grouped under low hazard and only ammonium phosphate was defined as moderately hazardous.

Table 2 : Concentration of heavy metals in phosphatic fertilizers,derived from Algerian phosphate rock of "Djebel Onk" deposit, in percentages.

Composition	Superphosphate		Ammonium phosphate	Granfos	
	Grade A	Grade B		Grade A	Grade B
Phosphorus Oxid (V)	21	20	Not less 19	29	29
Nitrogen	-	-	Not more 3	0,6	-
Manganese general	$8*10^{-4}$	$8*10^{-4}$	$8*10^{-4}$	$60*10^{-4}$	$70*10^{-4}$
Manganese water-soluble	$5*10^{-4}$	$5*10^{-4}$	$5*10^{-4}$	$< 5*10^{-4}$	$< 5*10^{-4}$
Cadmium general	$7,5*10^{-4}$	$8,3*10^{-4}$	$7,5*10^{-4}$	$14,3*10^{-4}$	$11,4*10^{-4}$
Cadmium water-soluble	$3,3*10^{-4}$	$3,7*10^{-4}$	$4,8*10^{-4}$	$1*10^{-4}$	$1*10^{-4}$
Lead general	$2,2*10^{-4}$	$2*10^{-4}$	$2*10^{-4}$	$2,9*10^{-4}$	$3,9*10^{-4}$
Lead water-soluble	$< 1*10^{-4}$	$< 1*10^{-4}$	$< 1*10^{-4}$	$< 1*10^{-4}$	$< 1*10^{-4}$
Copper general	$8*10^{-4}$	$8*10^{-4}$	$8*10^{-4}$	$10*10^{-4}$	$16*10^{-4}$
Copper water-soluble	$4*10^{-4}$	$4*10^{-4}$	$4*10^{-4}$	$< 1*10^{-4}$	$< 1*10^{-4}$
Zinc general	$120*10^{-4}$	$130*10^{-4}$	$120*10^{-4}$	$160*10^{-4}$	$230*10^{-4}$
Zinc water-soluble	$55*10^{-4}$	$65*10^{-4}$	$75*10^{-4}$	$40*10^{-4}$	$16*10^{-4}$
Mercury general	$1*10^{-4}$	$7*10^{-4}$	$1*10^{-4}$	$7*10^{-4}$	$1*10^{-4}$
Water-soluble Mercury	$< 2*10^{-4}$	$< 2*10^{-4}$	$< 2*10^{-4}$	$2*10^{-4}$	$2*10^{-4}$
Cobalt general	$6*10^{-4}$	$6*10^{-4}$	$6*10^{-4}$	$7*10^{-4}$	$6*10^{-4}$
Cobalt water-soluble	$4*10^{-4}$	$4*10^{-4}$	$4*10^{-4}$	$2*10^{-4}$	$2*10^{-4}$
Nickel general	$13*10^{-4}$	$15*10^{-4}$	$13*10^{-4}$	$18*10^{-4}$	$15*10^{-4}$
Nickel water-soluble	$10*10^{-4}$	$10*10^{-4}$	$10*10^{-4}$	$5*10^{-4}$	$5*10^{-4}$
Chrome general	$160*10^{-4}$	$120*10^{-4}$	$140*10^{-4}$	$210*10^{-4}$	$195*10^{-4}$
Chrome water-soluble	$100*10^{-4}$	$100*10^{-4}$	$100*10^{-4}$	$< 5*10^{-4}$	$< 5*10^{-4}$
Arsenic general	$6*10^{-4}$	$5*10^{-4}$	$3*10^{-4}$	$3,3*10^{-4}$	$3,9*10^{-4}$
Arsenic water-soluble	$1*10^{-4}$	$1*10^{-4}$	$1,2*10^{-4}$	$0,57*10^{-4}$	$0,71*10^{-4}$

Table 3 : Concentration of heavy metals in phosphatic fertilizers, derived from Tunisian phosphate rock of “Gafsa" deposit, in percentages.

Composition	Ammonium phosphate	Monoammonium phosphate
		Diammonium phosphate
Phosphorus oxide (V)	16,6	44-52
Nitrogen	4,3	11-18
Magnesium general	0,07	2,33
Magnesium water-soluble	0,005	0,43
Cadmium general	$13*10^{-4}$	$17,6*10^{-4}$
Lead general	$<1*10^{-4}$	$1,5*10^{-4}$
Arsenic general	$2,2*10^{-4}$	$5,2*10^{-4}$
Copper general	$4,8*10^{-4}$	$0,1*10^{-4}$
Copper water-soluble	$0,6*10^{-4}$	$4,5*10^{-4}$
Zinc general	$0,01*10^{-4}$	$2,32*10^{-4}$
Zinc water-soluble	$0,3*10^{-4}$	$5,8*10^{-4}$
Nickel general	$1*10^{-4}$	$7,14*10^{-4}$
Nickel water-soluble	$1,1*10^{-4}$	$4,47*10^{-4}$
Cobalt general	$0,5*10^{-4}$	$5,3*10^{-4}$
Cobalt water-soluble	$1,1*10^{-4}$	$3,9*10^{-4}$
Manganese general	$1*10^{-4}$	$10,36*10^{-4}$
Manganese water-soluble	$0,4*10^{-4}$	$5,42*10^{-4}$
Chrome general	$1,3*10^{-4}$	$32,37*10^{-4}$
Chrome water-soluble	$0,4*10^{-4}$	$3,38*10^{-4}$
Strontium general	$1,8*10^{-4}$	$2,4*10^{-4}$
Strontium water-soluble	$1,5*10^{-4}$	$1,3*10^{-4}$
Mercury general	$0,7*10^{-4}$	Tracks

The conclusions made on the fertilizers research analyses are as follows : for the compounds derived from the phosphate rock of Tunisia, monoammonium phosphate and diammonium phosphate are defined as low hazard products, and that ammonium phosphate classified as moderately hazardous.

The results of radiological researches on fertilizers are shown in Table 4.

Table 4 : Results of radiological researches of phosphatic fertilizers derived from the phosphate rock of Algeria and Tunisia .

Fertilizer	Summary effective radionuclid activity BKU/kg
Grade “Superphosphate A" from Algerian Phosphate Rock	161
Grade “Superphosphate B" from Algerian Phosphate Rock	161
Ammonium phosphate from Algerian Phosphate Rock	204-340
Grade Granfos B from Algerian Phosphate Rock	533
Ammonium phosphate from Tunisia Phosphate Rock	260

The results obtained from the total effective radionuclid activity were considerably lower than the recommended rate for fertilizers operating in Ukraine, which is not more 1860 BCU/kg.

Thus, taking into account the results of the toxicological researches of mineral fertilizers derived from the phosphate rocks from Algeria and Tunisia, the conclusions are that the raw materials are safe under the process conditions and the products can be safely used at the rates tested in Ukrainian soils.

On order to study fertilizers on the influence of soil self-recovery and migrations processes of heavy metals in agricultural production (barley, peas, wheat) a simple field control experiment using ammonium phosphate from Algerian phosphate rock was conducted. Superphosphate was applied in spring on field control plots with barley, peas and wheat at a rate of 60 kg and 600 kg per hectare. Soil analysis and agricultural yields were analyzed for the concentration of heavy metals at the end of the vegetation period (next to harvesting). The results were compared with the control plot, where agricultural production took place without the use of fertilizers. The concentration of heavy metals in soil after the influence by fertilizers is shown in Table 5.

Table 5 :Concentration of heavy metals in soil after dressing by fertilizers in mg/kg.

Name of heavy metal	Contence of heavy metals in soil without fertilizers	Contence of heavy metals in soil after dressing fertilizers		"PDK"* In soil
		60 kg P_2O_5 /Hectare	600 kg P_2O_5 /Hectare	
Cadmium	0,02±0,01	Trace	Trace	No rate
Copper	0,17±0,03	0,15±0,07	0,13±0,03	3,0
Mercury	0,3±0,01	0,3±0,01	0,3±0,02	2,1
Nickel	1,7±0,4	1,5±0,3	1,8±0,06	4,0
Lead	1,4±0,57	5,5±0,69	3,7±0,9	32,0
Zinc	1,2±0,4	1,33±0,5	1,85±0,1	23,0
Arsenic	0,9	1,4	1,9	2,0

* - The size of maximum permissible concentration of heavy metals in soil, in accordance with requirements, operating in Ukraine.

The results in Table 5 of atomic spectrometric soil analysis show that, adding 60 kg per hectare and 600 kg per hectare of fertilizers, the concentration the heavy metals on arable surface does not exceed the background indexes and maximum permissible concentrations for soils.

Table 6 shows the results of experiments on the migration of heavy metals in agricultural production.

Table 6 : Concentration of heavy metals in agricultural production after application of fertilizers.

Agricultural culture	Experiment Variant	Contence of heavy metals, mg/kg					
		Pb	Cu	Cr	Co	Cd	As
Barley	Without fertilizer	0.15	2.69	0.11	1.54	0.008	0.09
	Fertilizer 60 kg P2O5 / hectare	0.19	2.76	0.10	1.15	0.009	0.11
	Fertilizer 600 kg P2O5 / hectare	0.18	2.33	0.12	0.98	0.021	0.12
Peas	Without fertilizer	0.13	1.86	0.09	2.15	0.013	0.08
	Fertilizer 60 kg P2O5 / hectare	0.14	2.08	0.10	2.09	0.014	0.08
	Fertilizer 600 kg P2O5 / hectare	0.15	2.14	0.12	2.04	0.012	0.09
Wheat	Without fertilizer	0.12	2.46	0.08	0.71	0.014	0.09
	Fertilizer 60 kg P2O5 / hectare	0.14	2.33	0.09	0.78	0.009	0.10
	Fertilizer 600 kg P2O5 / hectare	0.16	2.34	0.09	0.80	0.006	0.10

Table 6 shows that all the production under different conditions with diverse amount of superphosphate do not result in the accumulation of heavy metals.

Conclusions:

The problem of heavy metals in phosphatic fertilizers is far from its solution, however researches, conducted in Ukraine in recent years, show that:

1. Total effective radionuclid activity of phosphate rock of the Mediterranean region and fertilizers derived from it is considerably below the rate permissible in Ukraine (not more than 1860 BCU/kg).

2. Phosphate rocks of the North African, Near and Middle East countries possess micro-elements and heavy metals of low hazard to human beings.

3. Phosphatic fertilizers produced from phosphate rocks from Algeria, Tunisia and Syria do not represent a threat to population health at rates evaluated, and conform to the sanitary-hygienic regulations.

4. Crops exposing to the influence of phosphatic fertilizers produced from North African raw materials, do no result in the accumulation of toxic elements.

Thus, the phosphatic fertilizers, produced in Ukraine from North African raw materials do not perform worse on ecological indexes compared to reputed international sources when applied under observed conditions and at normal rates to soils.

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