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# Perspectives of development of preparations for agriculture on the basis of nano-particles

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**The purpose.** To show perspectives of application of nano-particles in development of new and perfecting of existing preparations for various branches of an agriculture. **Methods.** Analysis of bibliographic sources, synthesis, generalization. **Results.** Scientists of many countries of the world convincingly prove high performance of use of nano-particles of metals and non-metals in various branches of national economy, including agriculture. The expediency of use of nano-particles of different elements for presowing treatment of seeds, foliar top dressing, protection of crops against diseases and pests is shown. Perspectives of their use are proved by development of immunobiological preparations, diagnostic aids, and nano-sensors. Perspectives of use of nano-particles and nano-techniques in forage industry, animal husbandry and veterinary medicine are shown. Despite of significant reaching of world nano-biology and considering weighable experience and scientific potential of domestic scientists in this sphere of science, the authors propose development of the State target scientific and technical program «Nano-techniques in agriculture» for 2021-2025. **Conclusions.** Necessity of comprehensive study of influence of nano-particles on an organism of animals, crops, microorganisms of soil and intestine of animals, pathogens of plants and animals, development of efficient nano-preparations and techniques of their application is dictated by the time. High performance of use of nano-particles (NP) of metals and non-metals in various branches of agriculture is determined. The expediency of use of NP of different elements for presowing treatment of seeds, foliar top dressing, protection of crops against diseases and pests is proved. Perspectives of use of NP are proved by development of immune-biological preparations, diagnostic methods and nano-sensors. Perspectives of use of NP and nano-techniques in forage industry, animal husbandry and veterinary medicine are shown.

***Key words:*** *diagnosis, nano-techniques, quantum points, nano-fertilizers, diseases, pests.*

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Nanoparticles (NFs) attract scientists' attention because of their unique and new properties, which completely differ from the properties of larger particles of the same materials and make

nanoparticles suitable for use in many branches of science and technology. BF is used for the detection of toxins and pathogens, diagnosis and treatment of diseases, biomarketing, delivery of drugs, chemical and biological analysis, for visualization in nonlinear optics, photovoltaics, catalysis and many other industries [1].

A nanoparticle is a solid-phase object with at least one dimension less than 100 nm, including artificial and biological particles, ultra-small particles of the environment [2]. Solid particles of less than 1 nm are usually referred to as clusters, and more than 100 nm to submicron particles. Tiny particles or nanocrystals of semiconductors with a diameter of 2-10 nm (10-50 atoms) are called quantum dots [3].

A designed or manufactured nanoparticle – is a particle that has been designed or manufactured by a person in a nanoscale to obtain special properties and functions that are associated with its size, has a specific physicochemical composition and structure. The projected BFs include particles with homogeneous composition and structure, compositionally and structurally heterogeneous particles (for example, core-corona particles) and multifunctional particles (for example, "smart" NPs, designed for medical diagnostics and treatment) [2].

NPs can exist in the form of agglomerates or aggregates - a collection of particles held together at the expense of the weak (the forces of Van der Waals, electrostatic interactions, etc.) and the strong (bonds formed during baking, etc.) forces. Typically, "agglomerates" are called only those accumulation of LF, which are held together as weak and strong forces. Under the "aggregates", respectively, are understood the accumulation of particles that are held together by a narrow spectrum of forces. But it should be noted that many authors do not recognize the difference between these terms and position them as interchangeable [4].

NPs can have different shapes: spherical, triangular, cubic, polyhedral, spindle-shaped, wire-like and even tadpole-shaped [5].

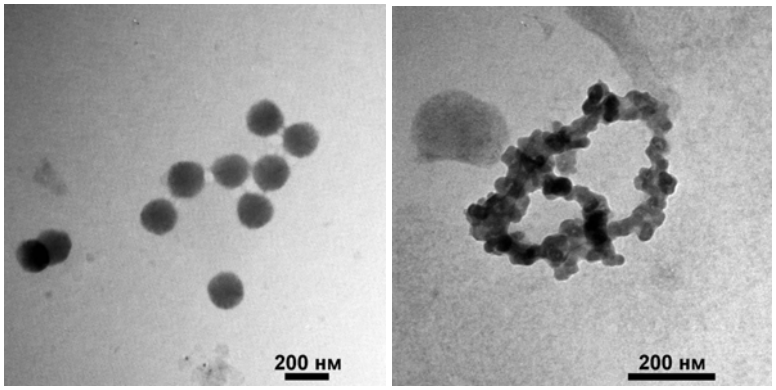
Recently, leading researchers have drawn attention to the possibility of using nanotechnologies in agriculture through the prospect of making a revolution in this field of human activity [6, 7]. It is the use of nanotechnology to provide new tools for increasing crop yield and productivity of domestic animals, as well as for molecular control and rapid diagnosis of their diseases [8].

At the same time, nano-fertilizers, disinfectants, medicines, biomaterials, vaccines, immunobiological agents, etc., which include low-frequency metals and nonmetals, require the development of a new methodology for their control and testing in the process of development and research, including the detection of cytotoxic effects and genotoxicity of nanomaterials (NM). [9]

**Nano-fertilizers and plant protection products**

Today, nanosized fertilizers of prolonged action are already widely used [10]. In the last decade nanosized fertilizers also appeared in our country. Thus, the patent of Ukraine protects the use of "Avatar-1" and "Avatar-2" drugs containing citrate and succinatochelets of nutrient elements in nanoscale form [11]. Presence in the preparation of LF is confirmed by transmission electron microscopy (Fig. 1). The results of microscopy allow to state the presence of different types of LF in the preparation, differing in form, size, electron density, predisposition to aggregation and adsorption, type of atomic structure. In particular, in the preparation, isolated single bases were found to have a correct spherical shape in the size up

to 100 nm, and polyhedral BF units up to 50 nm. The use of drugs greatly increases the crop yields [12].




a b

***Fig. 1. Electronic micrographs of nanoparticles (NPs) that are part of the drug Avatar-2: a – single spherical NPs, b – aggregated polyhedral NPs***

Thus, pre-planting of seed of winter wheat with composition of micronutrient drug Avatar-2 contributed to a 36.4% increase in yield [11].

It has been shown that NPs of Fe, Zn, Mn, Ag and Cu positively influence the growth and development of winter wheat, increase its yield by 20-25% [13].

In addition to the Avatar-2 drug, a number of NPs-based preparations have been developed and patented for use in various spheres of plant cultivation, in particular: a root crop fertilizer [14], a composition for increasing nitrogen fixation in crop production [15], a potato remedy from illnesses and Colorado beetle [16].

High biological activity of NPs, which are part of these drugs, is confirmed by fundamental researches of Ukrainian and foreign scientists.

**Bactericidal, fungicidal and virucidal properties of nanoparticles**

The use of organic antibacterial agents has significant limitations. Therefore, with the development of nanotechnology and the detection of antibacterial properties of NPs and other NMs, researchers have attracted the attention of potential antibacterial agents.

Due to the fact that the NPs are isolated solid-phase objects and consist usually of inorganic substances or of organic high molecular weight polymers, their degradation by bacterial cells is difficult. No cases of bacterial strains of resistance to NPs and other nanomaterials [17] have been described yet, which explains the high level of their antibacterial activity. These properties make the NPs and other NMs extremely promising for use as antibacterial agents in veterinary medicine, crop and other branches of agriculture. High biological compatibility of different nanoparticles has been shown [18-20].

Many of the researchers studied the antibacterial properties of low-dose copper oxide, which confirmed their activity against many bacteria, including *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Shigella* sp., *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, *Enterococcus faecalis*, *Shigella flexneri*, *Salmonella paratyphi*, *S. typhimurium* and *S. choleraesuis* [21-24]. It is noted that the antibacterial activity of LF oxide of copper depends on their size [23].

In general, antibacterial properties of the LF of many substances are reported: calcium oxides, magnesium, silicon, zinc, elemental silicon, silver, gold, nanocomposites ZnO-MgO, Ag-SiO2, Au-SiO2 and others [25-32].

Surface agents and ligands, such as poly-allilamine hydrochloride, can significantly increase the activity of the NPs [33].

Antiseptic drugs, the main active substances of which are low bands, have strong virucidal, bactericidal and fungicidal properties. An important feature of such drugs is that they are active against an extremely wide range of pathogens, including the most resistant ones, such as methicillin-resistant *Staphylococcus aureus*, lead-resistant *Pseudomonas aeruginosa*, *Aspergillus niger*, and *Candida* species [21, 34]. Another important feature is that such drugs do not induce the development of acquired resistance in microorganisms. In the available scientific patent database, we did not find any data on cases of resistance of microorganisms to the NPs.

In particular, domestic scientists have developed and patented a disinfectant containing water, NPs of silver and copper, their oxides and hydroxides, which is characterized by additionally containing silver carboxylate and copper carboxylate. The presence of low-frequency copper and carboxylates increases the antiseptic properties of low-carbon silver and leads to the formation of a synergistic effect [35].

Due to the high biocompatibility of the NPs, elements such as copper and silver have been used in wound healing ointments [36-38]. Prospective for use in this area are also low-grade selenium, because their biological properties also combine antimicrobial activity with high biocompatibility.

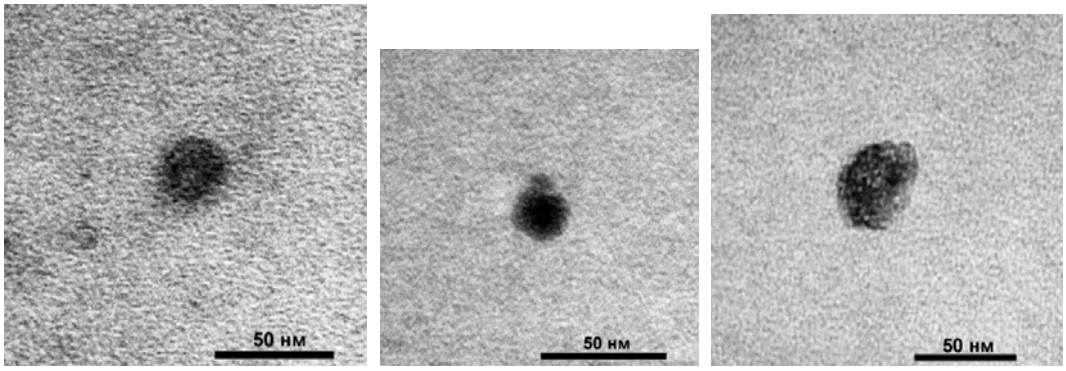
The use of liposomes, containing in its cavity aqueous solution of carboxylates of biogenic metals, provides an increase in the effectiveness of the composition, which ultimately leads to the possibility of reducing the concentration of active substances due to the high digestibility of the latter [39].

Viral infections are one of the main problems of humane, veterinary medicine and agriculture. Chemically synthesized antiviral drugs have adverse side effects that are associated with health complications. The emergence of new infectious diseases and the increase of virus-resistant drugs require the most effective and new therapeutic agents.

It has been established that some substances have low toxicity to cell lines in cell lines [40-43]. Due to its unique physico-chemical properties, NPs attracted the attention of scientists as potentially highly effective antiviral agents. It has been shown that LF can penetrate into infected cells and interact with the viral genome, block the cellular and viral factors that ensure replication of viruses [44]. NPs can block access to polymerases, thus preventing the replication and transcription of the viral genome [45]. There is reason to believe that NPs are associated with glycolipids superkapsids of complex viruses [46]. It has been shown that BFs can block the binding of virions to sensitive cells. During the study of antiviral activity of silver NPs, it was shown that they are often absorbed by cells of the experimental culture through endocytosis.

The high antiviral activity of the NPs of various substances has been proved. The researchers pay the greatest attention to the NPs of gold and silver, although it is also shown, the antiviral activity of NPs of copper iodide, copper oxide, cerium oxide, elemental selenium, gold / copper sulfide core / corona nanoparticles [47-56].

We have established the virucidal properties of NPs of Ti, Ni, and the composition of NPs of S and I in relation to *Teschovirus* [57]. We have investigated the mechanisms of antiviral action of NPs. The possibility of adsorption of the NPs on the surface of picornaviruses has been proved and the change in the morphology of viral capsids in the action of the NPs is shown (Figure 2).




*a* *b* *c*

***Fig. 2. Virion strain Teschovirus A Dniprovsky 32: a is a native virus; b – on the surface of the virion, the Si nanoparticle is adsorbed, and – the change in the morphology of the virion in the presence of Ce nanoparticles***

It has been established that NPs cerium dioxide possesses high antiviral and immunostimulating activity, which opens the prospects of developing on its basis nanocompositions capable of activating systems of cellular and humoral immune protection, prevention and therapy of viral diseases [58].

It should be noted that the activity of NPs in relation to phytoviruses is not fully understood. The antiviral activity silver NPs, obtained by biosynthesis, in relation to yellow bean mosaic virus [59] is shown. It is reported that treatment of NPs plants 24 hours after inoculation prevents the development of symptoms of the virus. In an accessible scientific-patent database, we did not find data on the antiviral activity of NMs in relation to other phytoviruses. Therefore, the search for antimicrobial activity against NMs and the development of antiviral drugs based on them is relevant.

Taking into account the unique physical, chemical and biological properties of NPs and NMs, screening for the presence of antimicrobial, antifungal and antiviral activity has an undeniable scientific novelty and significant practical significance.

**Nanotechnology in the development of diagnostic and immunobiological drugs**

In the fight against diseases of farm animals and with pests of plant crops, timely and qualitative diagnostics is important. The use of nanosensors in agriculture (NSs) is promising. The use of NSs in combination with the global positioning system will allow crop pests and stressors such as drought. NSs, made in the field, can detect the presence of phytoviruses and the level of nutrients in the soil [60].

Developed, also, NSs, which specifically react to auxins [61]. These sensors are a new step in the study of suction and transport mechanisms of auxins by the root system, the adaptation of plants to the environment, and others like that.

The use of the NSs may allow more efficient management of resources by monitoring the water status of crops and the receipt of nutrients on a time and spatial scale [62, 63]. Quantum dots are often used to design NSs (Fig. 3).

Immunobiological delivery systems, new techniques in molecular biology and cytology, new diagnostic tools and new drugs for disease protection are just some examples of the prospects for nanotechnology applications in agriculture.

For more than two centuries, vaccines are at the forefront of human and animal health. One of the challenges in developing effective systems is the need for an effective and safe adjuvant that would induce a strong adaptive immune response. During the last two decades, NMs has attracted attention as potential agents for the delivery of antigen and adjuvants.

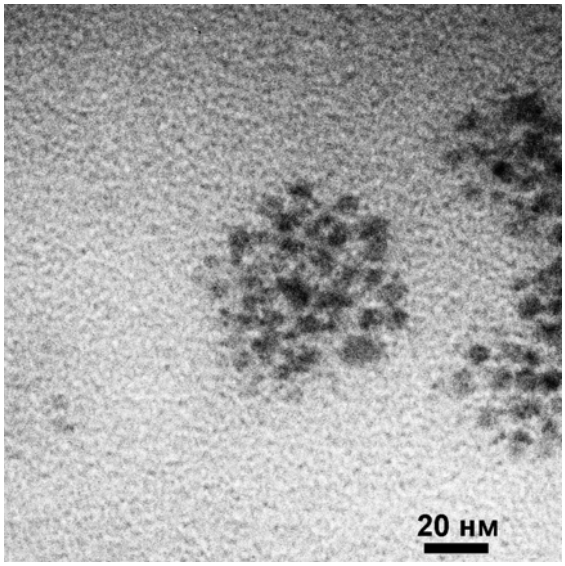



***Fig. 3. An electronic micrograph of quantum dots of cadmium selenide***

In experiments in mice, it has been shown that, in the group of vaccines against the herpes virus type 2 and the Epstein-Barr virus, NPs of calcium phosphate is more effective than traditional adjuvants [64]. They do not cause or cause only minor inflammation at the site of administration, induce high titres of the immunoglobulin G2a (IgG2a) and neutralizing antibodies, increase the percentage of resistance to the herpes virus of type 2. Additional benefits include insignificant IgE responses, which are an important advantage over traditional adjuvants, and the fact that calcium phosphate is a natural component of the human body and animals.

A delivery system consisting of a chitosan core to which the surface antigen of hepatitis B virus (HBsAg) has been adsorbed and is coated with sodium alginate [65] has been developed. Introduction to mice of HBsAg-encoded nanoparticles induces a high titre of anti-HBsAg IgG (2271 ± 120 mIU / $cm^3$) with a significant proportion of antibodies of the Th2 type. Although no significant difference was observed in the antigen-specific proliferation of splenocytes, IFN-γ and IL-4 secretion compared to the control group. The introduction of the NPs-encoded antigen together with the immunopotentiator CpG ODN 1826 causes an increase in the ratio of IgG2a / IgG1 from 0.1 to 1.0 and IFN-γ production by splenocytes [65].

It has been shown that during oral vaccination, the incorporation of antigens in the NPs protects antigens from degradation and enhances absorption of intestinal epithelium by M cells (Bram Slütter, 2009). Thus, in vitro studies, NPs N-trimethylchitosan act as adjuvants, enhancing the binding of antigen to dendritic cells [66].

Attract attention as an effective adjuvant to the mesoporous NPs silicon. It has been shown that mice immunization with the bacterial recombinant Intβ protein and snake venom proteins (*Mircurus ibibocoa*), mesoporous NPs silicon, are more effective adjuvants than traditional silicon hydroxide [67]. These results were confirmed by other researchers [68].

Thus, many studies have shown that HMs are more effective adjuvants than traditional counterparts. HMs, such as calcium phosphate NPs, chitosan, and silicon, not only improve the binding of antigens to the immune system cells and induce a much larger titer of immunoglobulins than traditional adjuvants, but are also biocompatible and do not exhibit toxicity. Therefore, NMs are extremely promising for use as adjuvants. The effectiveness of nano-adjuvants has been repeatedly confirmed on animal models, and therefore they are promising for use in animal husbandry.

Given the high efficiency of nano-adjuvants and the importance of animal husbandry for the country, the development and production of immunobiological drugs using nanotechnologies can become an important direction of the domestic economy.

**Prospects for the application of nanoparticles in livestock**

The influence of the NPs on the life processes and the commodity indices of farm animals is intensively studied. It is shown that the influence of nanocarticles of such elements as Se, Cr and Fe differs from the influence of other compounds of these elements. In particular, in the composition of nanoacqualites, these elements are characterized by increased physiological activity and intensively absorbed in the digestive tract [69].

It was established that the addition of Cr, Se, Co and Zn citrates to the cows diet during the first month of lactation promotes the growth of detoxification function of the liver, improves the metabolism of Ca, P and vitamin E. Mineral supplement stimulates secretory activity of the mammary gland, increases the average daily milk intake from cows by 3 , 3 - 7.8% [69].

Citrate-capped NPs of elements such as Fe, Zn, Mn, Cu and Co are more active than their inorganic salts. It is shown that they influence the metabolism parameters in the blood of piglets at concentrations of 10 times smaller, in concentration of inorganic salts [70]. In particular, the use of nanocitracts of these elements increases the antioxidant enzymatic activity of erythrocytes, the content of total protein, hemoglobin, the number of red blood cells.

Under the conditions of complex application of Fe, Zn, Mn, Cu, Co NPs in feeding pigs, the adaptive capacity of their organism during the period of weaning from sows increases due to the stimulation of the functional activity of antioxidant systems, resistance and increased resistance of animals to diseases [70].

The method of prevention of enzymes deficiency anemia of piglets is developed, which consists in the introduction of an animal preparation containing iron citrate, obtained using nanotechnology [71].

The method of nanocorrection of the microelement composition of feed for animals, which consists in introducing into the composition of feed NPs of zinc, magnesium, manganese, iron,

copper, cobalt, molybdenum, selenium, boron or iodine, which receive erosion-explosive dispersion of granules of the corresponding elements [72] is proposed.

It has been shown that cerium dioxide in the form of a low gas can be effective in increasing the productivity of poultry. Its application contributes to increasing the growth of live weight of the body of the bird, accelerates the development and the beginning of fertility, as well as reduces feed costs per unit of body weight gain [73].

In experiments on large cattle, the stimulatory effect of NPs citrates on chromium, selenium, copper, cobalt, iron, zinc and germanium is shown. [74].

Thus, high efficiency of the use of metals and nonmetals NPs in various branches of agriculture has been proved. It is shown the expediency of using different parts of the NPs for pre-sowing seed treatment, foliar nutrition, protection of crops against diseases and pests. The promise of their use in the development of immunobiological drugs, diagnostic tools and nano-adjuvants has been proven. The prospects of the use of NMs and nanotechnologies in feed production, animal husbandry and veterinary medicine are shown.

Taking into account the significant achievements of world nanobiology and taking into account the considerable experience and scientific achievements of domestic scientists in this field of science, we propose the development of the State target scientific and technical program "Nanotechnology in agriculture" for 2021-2025 years. The need for a comprehensive study of the impact of NPs on the organism of animals, agricultural crops, microorganisms of the soil and intestines of animals, pathogens of plants and animals, development of effective nanoparticles and technologies of their application are dictated by time.

## *Conclusions*

*The development of NPs-based drugs and the technologies of their application in various branches of agriculture in order to increase the implementation of the agrarian potential of the state is extremely important task of considerable scientific and practical importance.*

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