Journal of International Scientific Publication:
Materials, Methods & Technologies, Volume 3

NANOPARTICLES AND NANOMATERIALS: CHEMISTRY, INTERACTIONS, ENVIRONMENTAL AND BIOMEDICAL IMPLICATIONS

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Abstract

Nanoscience involves the study of materials on the nanoscale level between approximately 1 and 100 nm and involves study of how to control the formation of two- and three-dimensional assemblies of molecular scale building blocks into well-defined nanostructures or nanomaterials. Among novel nanomaterials, nanoparticles (NPs, with all three dimensions between 1 and 100 nm) play an important role in nanotechnology advances in the production of nanoscale materials and the rapid increase of their applications in many areas.

Key words: *nanoparticles, nanomaterials, implications*

1. INTRODUCTION

Not unlike the situation in conventional technology, materials are a critical if sometimes underappreciated component in achieving the goals of nanotechnology. A central construct of materials science and engineering is that the structure and processing of a material give rise to its properties, which in turn determine its performance in use. This certainly applies to nanomaterials as well and provides a useful framework for understanding in a familiar context. Nanomaterials have been important in the materials fi eld for quite a long time. an early example was the incorporation of gold nanoparticles in stained glass in 10 A.D.

Nanotechnology and the use of nano-scale materials is a relatively new area of science and technology. Nanotechnology is the intentional and controlled generation, or modification of materials at the nanometer (nm) scale. Although nano-scale materials have been used in the modern context of materials research for at least a decade (e.g., Buckminster fullerenes or C60), there is now a wider debate about the risks and benefits of the many manufactured nanomaterials and consumer products now appearing on the market. The benefits of nanomaterials are potentially enormous, and are still being explored.

There are as yet no internationally agreed formal definitions of nanomaterials (NMs) and NPs, but NMs are usually taken to be material with at least one dimension between about 1 nm and 100 nm [1-2]. These could be materials such as nanofilms (one dimension), nanowires and nanotubes (two dimensions), or nanoparticles (three dimensions). However, this definition of materials with a <100 nm dimension is arbitrary, and for ecotoxicology we should apply a broader definition that might include materials of a few hundred nm. A precise size threshold in this definition is not intended, since it is the novel toxic effects due to small size that are of interest. However, a pragmatic solution might be to consider materials with a primary dimension of <0.5 μm to differentiate nanoscale from micrometer scale. Whatever pragmatic decision is made about size thresholds to define NPs, some flexibility is needed. For example it could be argued that a single solid particle of 0.5 μm diameter

might not be different from the behaviour of a slightly larger particle in the 1–2 μm range. However aggregates with an overall dimension in the lm range, but made of primary particles of <100 nm would be regarded as a NM. Clearly for NPs, the primary particle size should be considered (e.g., the diameter of a single particle). In addition, the sizes of aggregates of NPs, which can be several hundred nanometers or more, and the distribution of particle sizes present in the material also need to be considered. In mammalian toxicology particles sizes (PM, particulate matter) have been defined as coarse particles (diameter between 10 lm and 2.5 lm, PM10–2.5), fine particles (2.5 μm or less, PM2.5), or ultrafine particles (<0.1 μm, PM0.1), so NPs could be regarded as ultrafine particles or smaller.

There are also unusual chemical and physical properties at the lower end of the nanoscale (e.g., 1–10 nm) and at the interface with the atomic scale. In particular, materials in the region from a few nm to several tenths of a nm exhibit properties (electronic states, magnetic and optical properties, catalytic reactivities) that behave differently from both their atomic/molecular level and from their larger particle counterparts. For example, quantum confinement effects have been observed in the electronic states of haematite leading to enhanced oxidation of Mn, even when normalised to SSA [4]. Size also has important control over other physical and chemical properties such as zeta potential and metal binding [5]. So there is also a concern that fundamental every-day assumptions about the chemical reactivity of molecules and atoms may need to be revisited when considering the ecotoxicity of NPs. Such quantum effects could also impart previously unknown toxic effects.

In addition, the variety of physical structures of NMs, (e.g., different crystal structures of the same material), and the potential for these structures to contain more than one substance (e.g., Ag–Ti composites as antibacterial coatings), or to be manufactured with multiple types of surface ligands, creates a new challenge for ecotoxicity testing.

2. TOXICOLOGY OF NANOPARTICLES

Extensive development of nanotechnology is not accompanied by adequate knowledge on the effect of nanoparticles on human health, which is virtually absent. However, even the first studies revealed the novel general and biological properties of the known materials, which they acquire when transformed into nanoparticles. For example, they penetrate into the cells and are selectively accumulated in various types of cells or in the compartments of similar cells. Nanoparticles can cross the epithelial and endothelial cell by transcytosis. Moreover, they travel along the dendrites and axons and the blood and lymphatic vessels provoking oxidative stress and inflammation [6-8]. Logically, the new academic discipline appeared and currently develops under the name of “nanotoxicology”, which is determined as “the science examining the effects of artificially designed nanostructures and the nanomechanisms on the living organisms [8]. Elaboration of the adequate approaches to prognosis of the risk of nanoparticles of various natures for human health is closely related to the study of the fundamental relationships in manifestations of their biological effects, and it is impossible to elaborate such approaches without comprehensive studies of this problem. The study of most general relationships in manifestations of the biological and toxic effects of nanoparticles depending on their shape, size, origin material, surface area, electric charge, physicochemical peculiarities of the structure, dosage, administration route, concentration in the target organ, and duration of action should be considered as the most important and actual fundamental problem of nanoparticle toxicology requiring immediate examination. Of particular importance is evaluation of the delayed effects of nanoparticles, including their effects on genome, immunity, and antenatal and postnatal development of the progeny. However, there are virtually no published data on these aspects. The theoretically outlined avenue of the wide use of nanoparticles in the development and production of new drugs needs principally novel

approaches to the preclinical safety assessment (PSA) of "nanodrugs". Existing PSA system is targeted to assess toxicity of chemical agents, but not toxicity of nanoparticles. The therapeutic preparations and nanoparticles designed on their basis can be principally different in the toxic properties due to significant peculiarities in kinetics and bioavailability *in vivo* [8] and possibly due to integration of the toxic and pharmacological effects of the initial chemical substance and its derivative nanoparticles.

3. INFLUENCE OF THE NP CHEMISTRY ON TOXICOLOGY

Evidence that physico-chemistry alters the ecotoxicity of nanoparticles As a research community, we are able to describe some of the fundamental physico-chemical behaviour of colloids and other particles, and we recognise that generally the ecotoxicology of chemicals (and particles) is altered by abiotic factors such as pH, salinity, water hardness, temperature, and the presence of dissolved organic matter in the water etc. However, this is an area where research is particularly lacking for manufactured NPs. To date, there have been few systematic ecotoxicological studies to investigate how changes in abiotic factors such as pH, hardness, ionic strength, or the presence of organic ligands in the water influence ecotoxicity.

The ecotoxicity of NPs in seawater compared to freshwater is also unclear. Experimental evidence from colloid chemistry in saline conditions suggests that even small increases in salinity above that of freshwater (e.g., 2.5 parts per thousand, ppt) can dramatically decrease colloid concentrations by aggregation and precipitation processes [9]. For many estuarine organisms such a small salinity change alone would have little biological effect, but this chemistry study predicts the rapid loss of colloid from the freshwater as soon as it enters the estuarine zone. This implies that toxicity tests in freshwater are not likely to be informative of toxicity in sea water, and further implies that sediment dwelling and particle filtering organisms in estuarine and marine ecosystems are likely to be important receptors for hazard assessment. Furthermore, the mechanisms of toxicity could be fundamentally different because organisms in freshwater and seawater will experience different physico-chemical forms of the same NP because of salinity effects on aggregation. At least one study has included some salinity experiments. [10] In the study, the authors exposed medaka eggs to fluorescent NPs (30 mg l-1) at a variety of different salinities. An increase in toxicity was seen with increasing salinity, along with a greater tendency for the particles to form aggregates. At a salinity of approximately 18.5 ppt the greatest fluorescence in the tissue (accumulation) was reached and 100% of the eggs were dead within 24 h. At higher salinities approaching that of normal seawater, accumulation decreased but the egg mortality rate remained high.

4. NANOPARTICLES /NANOMATERIALS - ENVIRONMENTAL APPLICATIONS

Clean water (i.e., water that is free of toxic chemicals and pathogens) is essential to human health. Clean water is also a critical feedstock in a variety of key industries including electronics, pharmaceuticals and food. The world is facing formidable challenges in meeting rising demands of clean water as the available supplies of freshwater are decreasing due to (i) extended droughts, (ii) population growth, (iii) more stringent healthbased regulations, and (iv) competing demands from a variety of users. Increasingly, water scientists and engineers are questioning the viability of the current practice of meeting the water demands of all users according to increasingly stringent standards [11]. Weber has proposed the distributed optimal technology networks (DOTNET) as an alternative to the 'huge centralized' water treatment plant. The DOT-NET concept is predicated upon the 'distribution and strategic placement of relatively small and highly efficient treatment systems at specific locations' in existing water supply networks. Such satellite water treatment systems would process relatively low

flow rates and would use 'off-the-shelf treatment technologies of the most advanced nature (e.g., supraselective foul-resistant membrane separations, customized polymeric adsorbents and molecular sieves, supercritical water oxidation, etc.)' to meet the water needs of population clusters such as housing subdivisions, apartment complexes and commercial districts [11].

The US Environmental Protection Agency (EPA) is also evaluating the use of a number of decentralized water treatment concepts as 'small system compliance technology' [12]. These include package treatment plants (i.e., factory assembled compact and ready to use water treatment systems), point-of-entry (POE) and point-of-use (POU) treatment units designed to process small amounts of water entering a given unit (e.g., building, office, household, etc.) or a specific tap/ faucet within the unit. The protection of water treatment systems against potential chemical and biological terrorist acts is also becoming a critical issue in water resources planning [13]. Advances in nanoscale science and engineering are providing unprecedented opportunities to develop more cost effective and environmentally acceptable water purification processes. This article gives a brief overview of the use of nanomaterials in the purification of water contaminated by toxic metal ions, radionuclides, organic and inorganic solutes, bacteria and viruses. Because a comprehensive discussion of the applications of nanotechnology to water purification is beyond the scope of this overview, our main objectives here are to discuss the opportunities and challenges of using nanomaterials in the purification of surface water, groundwater and industrial wastewater streams. There are four classes of nanoscale materials that are being evaluated as functional materials for water purification: (1) metal-containing nanoparticles, (2) carbonaceous nanomaterials, (3) zeolites and (4) dendrimers. These have a broad range of physicochemical properties that make them particular attractive as separation and reactive media for water purification.

Nanomaterials are the drivers of the nanotechnology revolution. Thus, a key bottleneck to the applications of nanotechnology to water purification will be the availability of suppliers that can provide large quantities of nanomaterials at economically viable prices. The Freedonia group has recently completed a study of the nanomaterials industry [14]. The study provides data on the demand of nanomaterials in the US for the years 2000 and 2003. It also includes forecasts of demand to the years 2008, 2013 and 2020 by classes of materials (e.g., metal oxides, clays, metals, polymers and chemicals, nanotubes, dendrimers, etc.) and by applications (e.g., abrasives; coatings, thin films, sunscreens; biocides; pharmaceuticals fillers and reinforcements; catalysts; structural materials, etc.). These forecasts anticipate that most nanomaterials will be nanoscale versions of established products such as silica, titanium dioxide, clays, metal powders, polymers and chemicals in the next decade [14]. Larger quantities of carbon nanotubes, fullerenes and dendrimers will also be available as these nanomaterials become key components of electronic products, drug delivery systems, batteries, fuel cells, etc. [14]. The integration of nanomaterials into existing water purification systems is another key challenge. Membrane processes such as RO, NF and UF are becoming the 'standard' water purification technologies for public utilities and industry because they are flexible, scalable, modular and relatively easy to operate and maintain. The DEUF process combines dendritic nanoscale chelating agents with commercially available UF membranes. Thus, it can be readily integrated into existing water purification systems or processes once a suitable and cost effective dendritic chelating has been selected or synthesized. However, more laboratory investigations and pilot scale testing will be needed to integrate novel nanostructured and reactive membranes into existing water purification systems.

The scale-up of TiO2-based photocatalytic reactors is also poorly understood ([15] even though significant progress is being made toward the development of visible light-activated TiO2 nanoparticles [16-18]. Conversely, we believe that nanosorbents (e.g., inorganic nanocrystals, carbonaceous nanoparticles and zeolites), redox active nanoparticles (e.g., Fe^0 and bimetallic Fe^0) and

bioactive nanoparticles (e.g., MgO and Ag) can be readily integrated into existing water treatment plants. Here a major challenge will be to develop cost effective and environmentally acceptable separation and reactive media that can be deployed in composite packed-bed reactors for purification of water contaminated by mixtures of (i) metal ions, (ii) organic solutes and (iii) bacteria. The environmental fate and toxicity of a material are critical issues in materials selection and design for water purification. Not much is known about the environmental fate, transport and toxicity of nanomaterials [19,20]. No systematic investigations of the hydrolytic, oxidative, photochemical and biological stability of nanomaterials (e.g., dendrimers, carbonaceous nanoparticles, metal oxides, et) in natural and engineered environmental systems have been published in the peer-reviewed literature to the best of our knowledge. A number of in vitro and in vivo measurements of toxicity and biodistribution have been carried out [21-23] in support of the use of dendrimers as DNA transfection reagents, metal ion contrast agent carriers for magnetic resonance imaging, targeted drug and therapeutic agent delivery vehicles and viral inhibitors [24]. These overall studies suggest that non-toxic and biodegradable dendrimers can be synthesized through a judicious selection of the dendrimer building blocks (e.g., core and terminal group). The design and synthesis of biocompatible carbon nanotubes (CNTs) and fullerenes are, on the other hand, much more challenging.

5. NANOPARTICLES /NANOMATERIALS - BIOMEDICAL APPLICATIONS

In recent years nanoparticles and nanomaterials become widely used for diagnostics and medical treatment. For example, Nanoprobes (USA) produces gold nanoparticles for diagnostics of cancer [25]: conjugates of antibodies against EGFR (epidermal growth factor receptor is not expressed by normal cells) with gold particles bound to tumor cells could be easily detected during microscopy of biopsy material [26]. PSivida (Australia) developed silica-based nanoparticles and nanocapsules for brachytherapy of inoperable hepatic cancer. Radioactive ^{32}P incorporated into such capsules kills tumor cells. Production of commercially available preparations begins in 2007 (http://www.psivida.com/default.asp). Starpharma (Australia) obtained permission for clinical application of dendrimer based gel (VivaGel, SPL7013) for prophylaxis of AIDS [27]. Nanoparticles as drugs have several important advantages, which include increased solubility and high rate of solubilization, increased bioavailability, rapid therapeutic effect, decreased risks of side effects [28]. For example, we have developed an injection form of the drug “Phosphogliv” [29]. The nanosystem, representing particles up to 50 nm in diameter, contains soybean phosphatidylcholine and glycyrrhizin. Clinical employment of Phosphogliv caused inhibition of replication activity of hepatitis B and C viruses and positive effect on immune interferon status. In clinical studies remission was 70% during treatment of hepatitis C [29-31]. Phosphogliv is characterized by low toxicity, it does not cause allergic reactions and it is stable during storage. New nanomaterials are now actively used both for the increase of effectiveness of “old” drugs and also for the development of new drugs. In this connection fullerenes attract much attention. Fullerenes are a new type of molecular form of carbon [32]. Each carbon atom is at a corner where two six-membered rings and one five-membered ring come together and basically cover the surface of a sphere or spheroid. Employment of fullerenes in biological and medical studies is based on their unique physico-chemical properties. C Sixty (USA) holds a leading position in studies of fullerens and their derivatives. Animal experiments revealed that fullerenes and their derivatives could repair damages originating in the result of oxidative processes in the cell [33–35]. Some of these compounds characterized by good biocompatibility and low toxicity are under clinical trials [36]. In human hepatoma cells Hep 3B carboxyfullerene C(60) inhibited TGF-beta induced apoptosis due to interaction with oxygen radicals formed in membrane [37]. The presence of carboxyfullerene C(60) prevented UV-induced apoptosis of human keratinocytes [38] and prevented mononuclear cells of peripheral blood against apoptosis under conditions of oxidative stress [39]. C3-

Fullero- tris-methanodicarboxylic prevented apoptosis of epithelial cells by changing their adhesive properties [40]. A unique property of fullerene and its derivatives consists in ability to penetrate blood-brain barrier [41] and therefore they may be used for treatment of acute and chronic neurodegenerative diseases such as Parkinson's disease. For example, experiments in rats revealed that the adduct of fullerene C(60) with polyvinylpyrrolidone prevented neuronal death and mpairments of long-term memory [42]. Much attention is paid to creation of such modifications of fullerenes, which would exhibit marked antiviral properties. For penetration inside cells viruses use receptors located on the plasma membrane surface [43]. Conformation changes of such receptors or their mechanical blockade by interaction of the C(60) fullerene molecule with ideal spherical structure and the size (of 0.7 nm) will complicate penetration of viral particle inside the cell. For example, fullerene C(60) with polyvinylpyrrolidone effectively inhibited replication of the influenza virus in experiments on chicken embryos and canine kidney cells [44,45]. A dose of fullerene was substantially lower than the corresponding parameter of rimantadine traditionally used for treatment of infection caused by influenza virus. In contrast to rimantadine, which is the most effective during early period of infection, the C(60) fullerene modified with polyvinylpyrrolidone was effective over the whole period of the viral replication cycle. Antiviral activity of fullerene C(60) derivatives was demonstrated for cytomegalovirus [46], vesicular stomatitis virus [47], hepatitis C virus [48]. Much of research on antiviral activity of fullerenes and its derivatives is associated with human immunodeficiency virus (HIV) [49-51]. Using computer modelling and based on X-ray data it was demonstrated that fullerene C(60) is complementary to the active site of HIV protease, where it is fixed by van der Waals bonds; this inactivates the enzyme and therefore interrupts the viral replication cycle [52]. In vitro experiments Tokuyama et al. [53] demonstrated the fulleren significantly reduced the rate of tumor growth of HeLa 33 cells. The derivative of fullerene, C(60)(OH)24, inhibited growth of human lymphocytes and epidermal sarcoma Hep-2 cells at the stage of mitotic spindle formation [54]. Using *E. Coli* cells as a model some studies demonstrated antibacterial properties of C60-bis(N,N-dimethylpyrrolidine iodide) and C60-bis(N,N-methylpyrrolidine iodide) [55-57]. Carboxyfullerene was also effective against streptococcal infections and therefore it may be considered as anti-microbial agent. In experiments on mice in vivo carboxyfullerene increased bactericide activity of neutrophils [58]. Positively charged derivatives of fullerene inhibited growth of *Mycobacterium tuberculosis* [59]. Experiments in mice revealed that carboxyfullerene prevented death of animals with meningitis induced by administration of *E. Coli* cells [60]. It is suggested that the antibacterial effect of carboxyfullerene is associated with its insertion into membranes of bacterial cells [61]. It is known that singlet oxygen formed in the result of photochemical reactions inactivates some viruses. For example, irradiation of a medium containing a photosensitizer based on C(60) and the virus Semliki Forest (SFV, *Togaviridae*) or vesicular stomatitis virus (VSV, *Rhabdovividae*) is accompanied by total loss of virulence of these viruses [62-64]. Tobata et al. Demonstrated [64] that intravenous administration of pegylated C(60) (fullerene modified with polyethylene glycol) to mice with fibrosarcoma caused its preferential accumulation in tumor and induction of necrosis. Additional photo irradiation caused total necrosis of the tumor [65]. These experiments indicate effective employment of fullerenes in photodynamic therapy of tumors. Some experiments demonstrated antitumor activity of fullerene C(60). For example, liposomes containing fullerenes were effective in therapy of uterine cervical cancer [66]. Andrievsky et al. [67] reported successful results of the first clinical trial of a preparation containing fullerene for the treatment of rectal adenocarcinoma. Fullerol $C(60)(OH)_{24}$ caused inhibition of growth of mammary gland tumor cells [68]. Thus, fullerenes and their derivatives exhibit various biological activities and their application in pharmacology has evident perspectives.

6. EXPERIMENTAL PART - FULLERENIC DERIVATES FOR BIOMEDICINE

Soluble fullerenic derivates are essential for numerous biomedical techniques that exploit the unique structural chemical and physical properties of carbon nanospheres [69-74]. Their toxicity, demonstrated in vitro and in vivo is important for the characterization and limitation of those applications. The phototoxicity of some fullerene molecules was identified as a future therapeutical instrument. Other studies focused on the decrease of the phototoxicity of hydrosoluble fullerenes follow the use of those compounds as drug delivery systems or their use in environment protection. Starting from the characteristics of those compounds, which can be by themeselves cytotoxic, or could become during irradiation (photosensitizers) the project's goal is to study in vitro C60 and C70 fullerenes, and some of their functionalized derivates, on experimental models in vitro with normal and tumoral cells, and the investigation of their toxicological and pharmacological profile, in order to identify new anti-neoplasic therapeutical instruments. In order to achieve this goal, in the first stage of the project C60 and C70 fullerenes were prepared and purified, as well as their complexes with PVP (poly-vinyl-pyrolidone) and with the oxo-dimer $(Fe\text{-}O)_2TPP$.

In the present report, is presented the synthesis and the characterization of some C60 and C70 complexes: μ-oxobis [5, 10, 15, 20-tetraarylporphyrinatoiron (III)] $(TXP\text{-}Fe)_2O$, where X= phenyl, naphthyl, tolyl, and μ-oxobis [5, 10, 15, 20-tetraarylporphyrinatomanganese (III)] $(TXP\text{-}Mn)_2O$, where aryl is phenyl or naphthyl.

The stoichiometry of those complexes is 1:1. μ-oxo-dimer complexes of trivalent metals (Mn, Fe) with different ligands – tetraphenylporphyrin (TPP) and tetranaphtylporphyrin (TNP) have similar structures. In the fullerene- μ-oxo-dimer complexes, the fullerene molecule is embraced in a pocket built by porphyrins (figure 1).

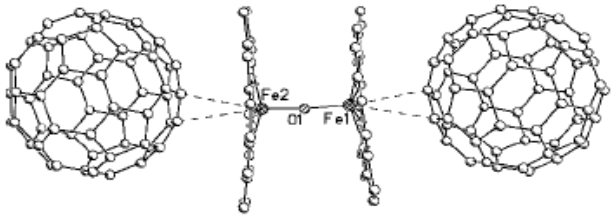


Figure 1. The iron compound synthesized in the study

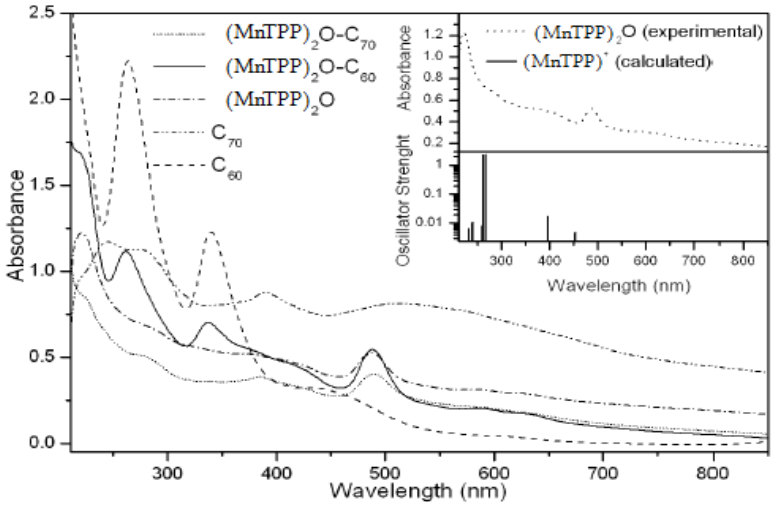


Figure 2. The UV-VIS spectra of fullerene-porphyrin compounds $[Mn(TPP0]_2O$

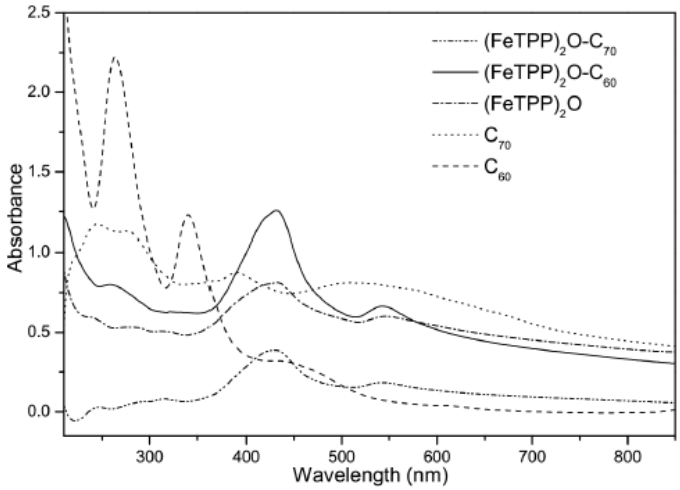


Figure 3. The UV-VIS spectra of fullerene-porphyrin compounds $[Fe(TPP0]_2O$

The Fe-μ-oxo-dimer-porphyrin was obtained by the typical method. After dissolving 0.5 g TPPFeCl in 60 ml $CHCl_3$ (1 hour reflux), 50 ml 25% KOH solution was added. The $(TPP\text{-}Fe)_2$-O compound was separated by chromatography on alumina column and eluted with chloroform.

This method is followed for $(TPP\text{-}Fe)_2$-O, $(TNP\text{-}Fe)_2$-O and $(TTP\text{-}Fe)_2$-O. The same synthesis method is suitable for the Mn compounds. Similar recipe has been used for $(TXP\text{-}Fe)_2$•C70 complexes. The crystals of $(TXP\text{-}Fe)_2$•C60 complex were obtained by slow evaporation of toluene solution containing 20 mg of C60 and 38 mg of $(TPP\text{-}Fe)_2$-O (1:1 molar ratio) under argon flow for a week (yield 90%). The complexes were characterized by UV-VIS and IR spectroscopy.

The purity of the synthesized systems was evaluated from the absorption spectra in different solvents:

- in Py, the monomer reacts leading to TPP-MeCl-Py, while the μ-oxo-dimer is inert to Py;

- in triethanolamine, the monomer reaches the μ-oxo-dimer form by polymerization.

The IR spectra identifies the Metal-Oxygen-Metal by it's vibration, corresponding to the band at 850 cm^{-1} (Mn-O-Mn) and 773 cm^{-1} (Fe-O-Fe); the δ values were found for the Metal-Oxygen bounds (525 cm^{-1} for Mn-O and 435 cm^{-1} for Fe-O) and Metal-N (449 cm^{-1} for Mn-N and 395 cm^{-1} for Fe-N).

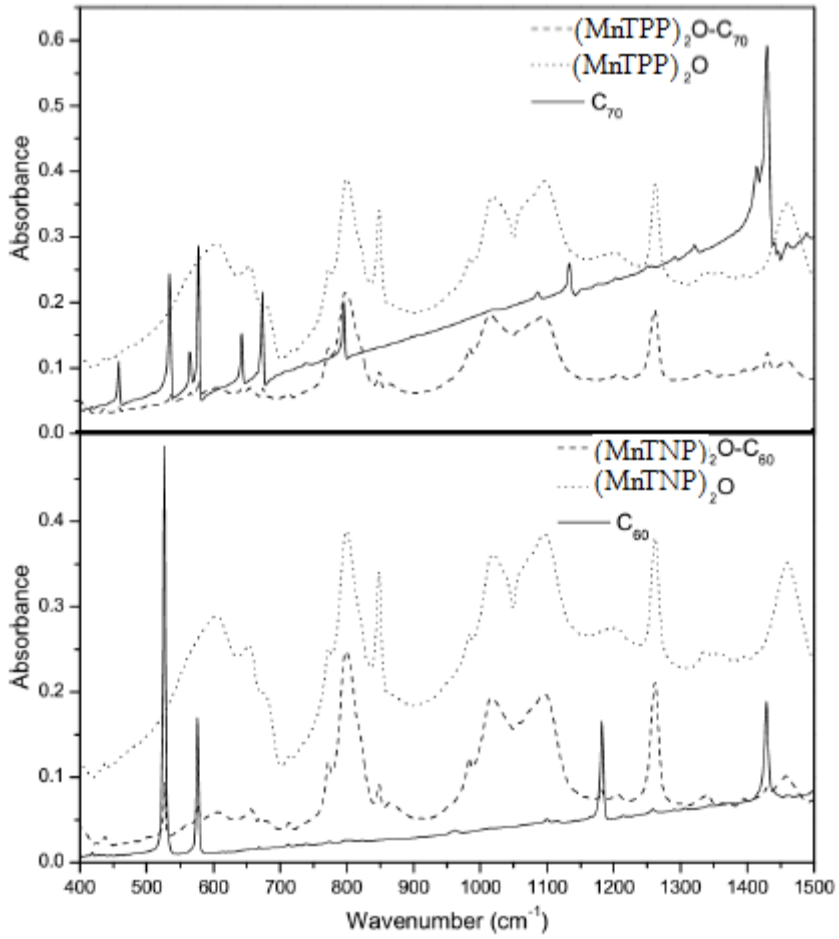


Figure 4. The IR spectra of the fullerene-porphyrin compounds $[Mn(TPP)]_2O$ si $[Mn(TNP)]_2O$;

Even if a series of porphyrinic compounds or nanostructures are already in different study stages, from pre-clinic to clinic, the mechanisms at cellular and molecular level, which are the base of the effects on biological systems and of their use in photodynamic therapy (PDT) are still the subject of scientifical controversy. Because most of the photosensitizers are amphyphilic and are partitioned in the lipid membrane layer, the activation by laser irradiation induces the destruction of the protein from the membrane level, and the singlet oxygen generated is diffused by the lipid membrane phase to the cytosolic phase. There are some proves that the mitochondria is the central coordinator of the mechanisms by which PDT induces apoptosis in the targeted cells. Recent studies demonstrate that the permeability of the external mitochondrial membrane favors the release of some pro-apoptotic factors in cytosol and the activation of the caspaze. The regulatory mechanism activated during PDT is dependent of the photosensitizer type, its dosage and of the type of the target cell. In laboratory research, nano-oncology offers certain promises in cancer treatment. As an example, nano-vectors can contribute to antitumoral drug-delivery and at the local destruction of the cancerous and pre-cancerous cells. Before those nano-instruments could be clinical applied, some preliminary studies are necessary, including toxicological evaluation. The possible toxicological problems associated to those nano-particles are to be investigated, right now being a deficit of data in this problem.

7. CONCLUSION

The paper presented a short review of present knowlege on nanomaterials and nanoparticles, as well as their environmental and biomedical implications.

We envision that nanomaterials will become critical components of industrial and public water purification systems as more progress is made toward the synthesis of cost-effective and environmentally acceptable functional materials. The development of smart membranes with biofilmresistant surfaces and embedded sensors/actuators that can automatically adjust membrane performance and selectivity by the near future is a key long-term goal of the scientifical world.

Initial concept of nanomedicine has orifinated from fantastic ideas of creation and introduction to the human body of "tiny" nanorobots and related mechanisms, which would responsible for cell repair at the molecular level. For example, a mechanical nanorobot injected into blood stream reaches the heart, "examines" it, detects a damaged valve and operates it using a micro scalpel. There is the other possibility: a microrobot administered to the patient's body finds and kills sick cells. If efforts of nanobiotechnologies are directed towards the development of new diagnostic methods and new drugs, the most important tasks of nanomedicine include medical nanorobots, nanomaterials for tissue bioengineering, and possibly (in the future) selfreplicating genomes [3]. There are perspectives that after 10–20 years the development and improvement of nanotechnologies results in employment of first nanorobots in the consulting rooms of general practitioners; this would give medical doctors effective "weapons" to fight against any disease. Examples of such nanorobots might be analogues of blood cells (erythrocytes, phagocytes, respirocytes, etc.) significantly exceeding effectiveness of functions of real blood cells. On the other hand, this will give new capacities for substitution of gene therapy for gene surgery. A nanorobot controlled by doctors will isolate a mutant gene from a single ill cell and introduce a normal gene into the same cell (and into right position). Possibility of cell penetration with the "laser scalpel" without impairments of the cell structure has recently been demonstrated. However, there are many technical problems, which should be solved on the way of creation of real medical nanorobots. Thus, introduction of nanotechnologies into biology and medicine will significantly extend their capacities in the nearest future.

In the experimental part, some fullerene-based functionalized nanomaterials were successfully synthesized and characterised.

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