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Selecting nanoparticles in the medical industry based upon AHP method

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ABSTRACT

Nanoparticles classified in 4 overall groups containing: Metallic nanoparticles, ceramic nanoparticles, polymeric nanoparticles and semiconductor nanoparticles. These nanoparticles are used in some biomedical applications such as carrying medicine and photographing agents. With attention to different criteria which are both qualitative and quantitative, selecting the most suitable nanoparticles is of great importance. In this research, we must verify the method of ranking and selecting the appropriate nanoparticles by using AHP method and the view of the experts of this industry. Results of this research show that with attention to all criteria for using in pharmacological and medical process, the most suitable nanoparticle is ranked in this position: semiconductor, metallic, polymeric and ceramic.

Keywords: *Nanoparticles; AHP method; Rating; Qualitative and quantitative criteria; Medical industry.*

INTRODUCTION

As we know, any new phenomenon has different positive and negative effects, then we can conclude the nanoparticles choice methods for using in pharmacological and medical industry, that are very considerable, because of the human being health. Nevertheless, therefore, some different quantitative and qualitative criteria for distinguishing the dominance of a method towards the others, which any of them may have different importance. In any case any nanoparticle has some advantages in some particular criteria. In these circumstances, the problem of the choice of nanoparticles should be converted and solved into a mathematical model. One of the most appropriate is using the AHP technique, which will be explained briefly in the other section of the paper. A nanoparticle, is a particle which its dimension is about 1-100 nm. Nanoparticles contain the combinational nanoparticles such as the 2 layer nuclear structures besides the metallic, insulators and semiconductor types. Nanoparticles are considered in lower sizes of nanoparticles.

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Also, nanospheres, nanorods and nanocubes are considered as shapes of nanoparticles. Nanocrystals and semiconductor quantum points are considered as subsets of nanoparticles. These nanoparticles have some applications in electronical, electrical and biomedical fields as drug career and photographic agents.

Nanotechnology has many applications in electronics, medical, pharmacological industries and etc. Indeed, the birth of this field is aligned with the famous lecture of "Richard Feynman", the famous professor in physics in California institute of Technology and his famous sentences: "there's plenty of room at the bottom" [1]. But, the new properties created from the substitution of atoms in this scale, brings up several questions such as manufacturing, consumption, health and environment setup some dangers for human being in the manufacture, using , and repelling steps?

Despite after more than 10 years from being sent the first nanomaterials to market and increasing application of this technology in pharmacological and electronic materials and industries, there is low information about its dangerous effects for environment, health and industries safety [2].

Maybe when these materials were produced for sending to market, nearly nobody noticed their hazardous properties for the health of human and environment, while some studies which being performed upon the biological reactions of some nanomaterials, showed that many nanoparticles affect upon the organisms of our body by breaking the layers [2]. Also they can affect our body by breathing, eating and skin and finally jetting into the blood. In recent years, the governments have wanted the governmental and nongovernmental, industrials and nonindustrial institutes to verify the health and environmental safety subjects and reducing their dangerous effects.

Introducing metallic, ceramic, polymeric and semiconductor nanoparticles

Nanotechnology refers to the branch of science and engineering dedicated to materials, having dimensions in the order of 100th of nm or less [3]. The term being new, but has been widely used for the development of more efficient technology. In recent years, nanotechnology has been embraced by industrial sectors due to its applications in the field of electronic storage systems [4] , biotechnology [5] , magnetic separation and preconcentration of target analytes, targeted drug delivery [6,7] , and vehicles for gene and drug delivery [4,6–8] . Consequently, with wide range of applications available, these particles have potential to make a significant impact to the society. Although new, the history of nanomaterials dates long back to 1959, when Richard P. Feynman, a physicist at Cal Tech, forecasted the advent of nanomaterials. In one of his class he said, "There is plenty of room at the bottom," and suggested that scaling down to nanolevel and starting from the bottom was the key to future technology and advancement [8]. As the field of nanotechnology advanced, novel nanomaterials become apparent having different properties as compared to their larger counterparts. This difference in the physiochemical properties of nanomaterials can be attributed to their high surface-to-volume ratio. Due to these unique properties, they make excellent candidate for biomedical applications as variety of biological processes occur at nanometer scales.

The use of biodegradable polymeric nanoparticles (NPs) for controlled drug delivery has shown significant therapeutic potential. Concurrently, targeted delivery technologies are becoming increasingly important as a scientific area of investigation. In cancer, targeted polymeric NPs can be used to deliver chemotherapies to tumor cells with greater efficacy and reduced cytotoxicity on peripheral healthy tissues. In this chapter, we describe the methods of preparation and characterization of drug-encapsulated polymeric NPs formulated with biocompatible and biodegradable poly(D,L-lactic-co-glycolic acid)-poly(ethylene glycol) (PLGA-b-PEG) copolymers; surface functionalization of the polymeric NPs with the A10 2'-fluoropyrimidine ribonucleic acid (RNA) aptamers that recognize the prostate-specific membrane antigen (PSMA) on prostate cancer cells; and evaluation of the binding properties of these targeted polymeric NPs to PSMA-expressing prostate cancer cells in vitro and in vivo. These methods may contribute to the development of other useful polymeric NPs to deliver a spectrum of chemotherapeutic, diagnostic, and imaging agents for various applications [9].

Semiconductor nanoparticles were synthesized by exposing fatty acid salt Langmuir-Blodgett films to the atmosphere of H_2S. The particle sizes were characterized by small-angle X-ray scattering of their solutions using synchrotron radiation source at higher resolution, as it was impossible previously to study it with usual laboratory X-ray sources. The particle sizes were found to correspond to the demands of single-electron and quantum junctions. Semiconductor heterostructures were grown by self aggregation of these particles of different types. Electrical properties of these nanostructures were studied by using STM. Voltage-current characteristics revealed the presence of differential negative resistance. Measurements confirmed the formation of semiconductor superlattices directed towards a development of new nanodevices, like tunneling diodes and semiconductor lasers [10].

Clay nanoparticles when incorporated into polymer matrices increase reinforcement, leading to stronger plastics, verifiable by a higher glass transition temperature and other mechanical property tests. These nanoparticles are hard, and impart their properties to the polymer (plastic). Nanoparticles have also been attached to textile fibers in order to create smart and functional clothing [11].

AHP method

Multi criteria decision making is one field of "OR" and "management sciences" which is developed with attention to the different applied necessities in the last decade rapidly. "Decision making" is a method for finding the best choice among a set of some present options. When we consider different criteria, we can name this method as "MCDM" (Multi Criteria Decision Making). AHP technique is one of these methods and has a vast and successful usage in many "DM" problems [12, 13].

In AHP method, first calculate the ration between criteria weight and the total value of any choice is calculated as the obtained weight [14, 15]. In comparison on with the other methods of MCDM, AHP is the most successful one [16]. Fei and his cooperators used AHP for selecting a successful environmental management system in 2008. After making all of the matrixes of even comparisons between the criteria and subcriteria, "CR" should be calculated.CI shows deviation from compromise [14]. If the obtained CR is lower than 0.1, the comparisons are acceptable and otherwise we should perform the comparisons with more information and more accurate by experts once again.

- ***The principles of AHP***

Thomas Saaty (the founder of this method) has explained four principles as the main ones. These principles are [17]:

- The reciprocal condition: if preference of element A upon element B is n, then preference of element B upon element A will be 1/n.
- The identity principle: element A should be homogenous and comparison table with element B. in other words, the preference element A upon element B cannot be infinitive or zero.
- Dependence: any element can be dependent to its higher level elements and in the linear form, this dependence can continue to the highest level.
- Expectations: whenever the changes are created in the AHP method, the verifying process should be done once again.

- ***The AHP process model***

Applying this method is based upon the 4 main steps:

1. Modeling: In this step, the DM aim and problem is changed into a hierarchy system of decision elements which are related together. The decision elements are "DM criteria", and "decision options". The AHP process needs the wreckage of a problem with several criteria and ringing it into a hierarchy system of levels. The high level explains the main aim of DM process. The second level shows the main criteria which maybe branched into the partial criteria in the next layer. The last layer presents decision options [17].

2. Preferable judgment (even comparisons): Performing some comparisons among the different options of decision, based upon any criteria judging about the importance of decision criteria with doing the even comparisons, is acted after the planning of hierarchy system of decision problem. The person who decides should make the matrix series which measures the relative preference or importance of criteria numerically towards together and any decision choice with attention to criteria towards the other options.

3. Calculations of the relative weights: Defining the weight of "decision elements" towards together is done by a set of numerical calculations for defining the priority of any decision element is necessary and this will be done by using the information of matrixes of even comparisons.

4. Combining the relative weights: In this step, we should multiply the relative weight of any element into the higher elements weight for getting the final weight. This work is done for ranking the decision options. By doing this step for any choice, the final weight value is obtained.

EXPERIMENTAL

This research is applied from the target's view and is descriptive- exploring from the research's view. In this way, the necessary information obtained by using the library method. Then, AHP technique which is one of DM methods was used. In this research, first one answer sheet was prepared with 7*7 dimensions containing the criteria even comparisons towards together and was transferred to the nano scientist. Also, 7 other answer sheets were completed in relation with any 7 criteria about the choiced even comparisons by him. Then, any matrixes converted into a normalized matrix and averaging was done.

Nanoparticles group (options) weight towards any criteria was multiplied by criteria weight vector. The value of any nanoparticle group calculated for using in pharmacological industry.

Modeling the problem

In this research, our aim is solving the problem of defining one of nanoparticles in 4 total group which are: metallic nanoparticles, ceramic nanoparticles, polymeric nanoparticles and semiconductor nanoparticles, and these nanoparticles are used in pharmacology, and medicine with attention to quantitative and qualitative criteria containing their effect, environmental contamination, time of removal form body, chasing easiness, measurement easiness, production easiness and economical profit. For these reasons, we use AHP decision making method. After gathering the initial information, based upon the principles of this method, we can define the solution of the problem. In the next section, we explain the solution steps in detail.

Ranking nanoparticles

For selecting a nanoparticle, with respect to qualitative and quantitative criteria, we must make logical decisions. Therefore, by using the AHP model and the view of experts in this industry, even comparisons matrix is prepared. After normalizing and verifying the compromising matrixes and passing the calculating steps, the importance of any nanoparticle is defined for applying in the medical sciences. For this purpose, first the even comparisons matrix is prepared and as an answer sheet has been given to expert of this industry and he voted about the preference of parameters towards together.

For solving the problem, in the first step parameter even comparisons matrix is prepared and in the second step, the normalized even comparisons matrix and the importance of different nanoparticles is calculated. In this step, we use the following relations. If the criteria has a positive role, is normalized with relation (1) and if it has a negative role, is normalized with relation (2). Meanwhile, if the criteria are quantitative, then no need for the formation of even comparisons matrix. Then we gain the mean in rows (Aij).

$$P_{ij} = X_{ij} / \sum X_{kj} \text{ (k=1 to m)} \qquad (1)$$

$$P_{ij} = 1- (X_{ij}/X_{j}max) \qquad (2)$$

Xij: the given value to the i^{th} choice with respect to j^{th} criteria

Pij: the normalized value of the Xij

In the third step, the whole score of any nanoparticle is calculated with respect to different agents such as affecting, environmental pollution, and etc., based upon the relation (3).

$$A_{i}= A_{ij} *C \qquad (3)$$

Ai: the vector of importance (weight) of options.

Aij: the weight matrix of any i^{th} choice in relation with j^{th} criteria.

C: the calculated vector of criteria weight

RESULTS AND DISCUSSION

With respect to the calculated weight for any nanoparticle (choice), we can decide about the most suitable nanoparticle. Taken results based upon the used procedure are reflected in these tables. The comparison of criteria towards together from the expert's view is shown in Table 1. Then, the normalized matrix for comparing the parameters towards together and calculating the criteria weight is prepared (Table 2). The importance of nanoparticles from view of quantitative criteria of time of removal from our body and economical profit is calculated in Table 3. The matrix of nanoparticles even comparisons from the view of affecting qualitative criteria is presented in Table 4. This matrix is normalized in Table 5. Similarity for environmental pollution, tail finding easiness, measuring easiness, production easiness qualitative criteria, we do the even comparisons in Tables 6-10 and 12. Then, the normalized matrix for them is calculated in Tables 7, 9, 11 and 13.

The total result of the weight matrix of any options (nanoparticles) in relation with the criteria is shown in Table 14.

By multiplying Criteria Weight from the last column of Table2 in the weight matrix of any options (nanoparticles) in relation with the criteria of Table 14, we obtain the importance of any nanoparticles in medical and pharmaceutical industry (Table 15).

Table 1. Comparison of criteria towards together from the expert's view

criteria	affecting	environmental pollution	time of removal from our body	tail finding easiness	measuring easiness	production easiness	economical profit
affecting	1	7	5	4	6	4	1/8
environmental pollution	1/7	1	5	5	6	1/7	1/6
time of removal from our body	1/5	1/5	1	4	1/4	2	1/5
tail finding easiness	1/4	1/5	1/4	1	1/4	1/3	1/5
measuring easiness	1/6	1/6	4	4	1	1/3	1/5
production easiness	1/4	7	1/2	3	3	1	1/5
economical profit	8	6	5	5	5	5	1

Table 2. The normalized matrix for comparing the parameters towards together and calculating the criteria weight

Criteria	Affecting	Environmental Pollution	Time Of Removal From Our Body	Tail Finding Easiness	Measuring Easiness	Production Easiness	Economical Profit	Criteria Weight
affecting	0.1	0.32	0.24	0.16	0.27	0.18	0.07	0.19
environmental pollution	0.01	0.05	0.24	0.2	0.27	0.01	0.09	0.12
time of removal from our body	0.02	0.01	0.05	0.16	0.01	0.17	0.1	0.09
tail finding easiness	0.03	0.01	0.01	0.04	0.01	0.03	0.1	0.03
measuring easiness	0.02	0.01	0.19	0.16	0.05	0.03	0.1	0.08
production easiness	0.03	0.32	0.02	0.12	0.14	0.08	0.1	0.12
economical profit	0.8	0.27	0.24	0.2	0.23	0.42	0.5	0.41

Table 3. Importance of nanoparticles from view of quantitative criteria of time of removal from our body and economical profit

Nanoparticles	Time Of Removal From Our Body	Economical Profit
Metallic	0.14	0.26
Ceramic	0.07	0.09
Polymeric	0.5	0.3
Semiconductor	0.29	0.35

Table 4. The matrix of nanoparticles even comparison from the view of affecting qualitative criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor
Metallic	1	1/2	1/5	1/8
Ceramic	2	1	1/5	1/9
Polymeric	5	5	1	1/6
Semiconductor	8	9	6	1

Table 5. The normalized matrix for comparison of nanoparticles from the view of affecting qualitative criteria and calculating the weight of these criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor	Weight
Metallic	0.06	0.03	0.03	0.09	0.05
Ceramic	0.13	0.06	0.03	0.08	0.08
Polymeric	0.31	0.32	0.14	0.12	0.22
Semiconductor	0.5	0.58	0.81	0.7	0.65

Table 6. The matrix of nanoparticles even comparison from the view of environmental pollution qualitative criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor
Metallic	1	1/4	2	1/9
Ceramic	4	1	4	1/8
Polymeric	1/2	1/4	1	1/9
Semiconductor	9	8	9	1

Table 7. The normalized matrix for comparison of nanoparticles from the view of environmental pollution qualitative criteria and calculating the weight of these criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor	Weight
Metallic	0.07	0.03	0.125	0.08	0.08
Ceramic	0.28	0.11	0.25	0.09	0.18
Polymeric	0.03	0.03	0.06	0.08	0.05
Semiconductor	0.62	0.84	0.56	0.74	0.69

Table 8. The matrix of nanoparticles even comparison from the view of tail finding easiness qualitative criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor
Metallic	1	1/2	5	1/9
Ceramic	2	1	6	1/8
Polymeric	1/5	1/6	1	1/8
Semiconductor	9	8	8	1

Table 9. The normalized matrix for comparison of nanoparticles from the view of tail finding easiness qualitative criteria and calculating the weight of these criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor	Weight
Metallic	0.08	0.05	0.25	0.08	0.12
Ceramic	0.16	0.1	0.3	0.09	0.16
Polymeric	0.02	0.06	0.05	0.09	0.06
Semiconductor	0.74	0.82	0.4	0.74	0.68

Table 10. The matrix of nanoparticles even comparison from the view of measuring easiness qualitative criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor
Metallic	1	9	7	4
Ceramic	1/9	1	1/4	1/5
Polymeric	1/7	4	1	1/9
Semiconductor	1/4	9	5	1

Table 11. the normalized matrix for comparison of nanoparticles from the view of measuring easiness qualitative criteria and calculating the weight of these criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor	Weight
Metallic	0.67	0.39	0.53	0.75	0.59
Ceramic	0.07	0.04	0.02	0.04	0.04
Polymeric	0.09	0.17	0.08	0.02	0.09
Semiconductor	0.17	0.39	0.38	0.19	0.28

Table 12. The matrix of nanoparticles even comparison from the view of production easiness qualitative criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor
Metallic	1	8	9	7
Ceramic	1/8	1	2	1/2
Polymeric	1/9	1/2	1	1/3
Semiconductor	1/7	2	3	1

Table 13. The normalized matrix for comparison of nanoparticles from the view of production easiness qualitative criteria and calculating the weight of these criteria

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor	Weight
Metallic	0.72	0,7	0.69	0.79	0.73
Ceramic	0.09	0.09	0.15	0.06	0.1
Polymeric	0.08	0.04	0.08	0.04	0.06
Semiconductor	0.1	0.17	0.23	0.11	0.15

Table 14. The weight matrix of any options (nanoparticles) in relation with the criteria

Factor	Affecting	Environmental Pollution	Time Of Removal From Our Body	Tail Finding Easiness	Measuring Easiness	Production Easiness	Economical Profit
Metallic	0.05	0.08	0.14	0.12	0.59	0.73	0.26
Ceramic	0.08	0.18	0.07	0.16	0.04	0.1	0.09
Polymeric	0.22	0.05	0.5	0.06	0.09	0.06	0.3
Semiconductor	0.65	0.69	0.29	0.68	0.28	0.15	0.35

Table 15. The nanoparticles (options) calculated weight for applying in medical and pharmaceutical industry

Nanoparticles	Metallic	Ceramic	Polymeric	Semiconductor
Weight Of Options	0.3131	0.1002	0.2248	0.4367

CONCLUSIONS

By using the AHP method and mathematical modeling based upon the needed and known criteria, the following results were obtained:
- The needed criteria from the view of expert (maker decision) are in the following importance level economical profit, affecting, production easiness, environmental pollution, time of removal from our body, measurement easiness, tail finding easiness.
- These four nanoparticles group from the view of applying them in medical and pharmaceutical industries have this importance ranking: semiconductor, metallic, ceramic and polymeric.
- This results are obtained from the view of an expect group is suggested.

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