Article
Public Awareness of Nanotechnology and Its Implications for Health in Jordan

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Abstract: Nanotechnology is often described as an emerging technology, holding promise for a diverse range of fields. Public awareness may have a strong impact on public acceptance of nanotechnology and its various implications. In Jordan, nano-education has only been introduced recently into universities and it is offered to students of pharmacy, engineering, biomedical sciences, and agriculture. However, there is no data available on nanotechnology awareness among the public in Jordan. Therefore, we conducted this study to evaluate Jordanian public awareness and concern about nanotechnology, nanomaterials, and nanoproducts and its implications for health related applications of nanotechnology. An online survey was developed consisting of 15 questions and separated into three domains. The study findings show that more than half of the respondents have a very low awareness with regards to nanotechnology and its various implications. Additionally, respondents show interest to learn more about nanotechnology and its implications, preferring several sources of information such as media, universities and research institutions.

Keywords: nanotechnology; implications; public understanding; awareness; health; Jordan

1. Introduction

Recently, a new branch of technology based on the manipulation of materials measuring 100 nanometers or less has been developed. This new technology is called nanotechnology. This discovery was a true climax of the bioindustry activities and, as such, it brought high expectations for great potentials that emphasizes the need for social scientific explanations to understand possible future cases in nanotechnology industries [1,2] and an investigation of public understanding of nanotechnology in science [3,4].

Nanomaterials have been defined as materials with at least one dimension smaller than 100 nm [5–7]. These materials include produced nanomaterials, such as diesel exhaust materials or airborne combustion by-products, as well as nanosized materials which occur in the environment, such as viruses or volcanic ash [8]. In general, nanomaterials offer relative surface areas bigger than the parallel common forms. Furthermore, the small size often leads to increased reactivity and the change of surface properties of some consumer products such as paints, food, cosmetics, suntan lotions, medicines, and applications that directly release nanomaterials into the environment, like the remediation of polluted environments [9].

According to the European Commission in 2012, there are global uses of nanomaterials. For example, in aerospace they are used to produce lightweight materials, resistant paints and coatings for aerodynamic surfaces [10]. In the automotive industry and transport they are used in scratch-resistant paints and coatings, plastics, lubricants, fluids, and tires. In agri-food they are used in sensors to optimize food production. In construction they are used in insulation, stronger building materials and self-cleaning windows. While in energy generation they are used in photovoltaics and storage like fuel cells and batteries. Nanomaterials can be used also in the environment for soil and groundwater remediation.
In cosmetics, they are used in sunscreens, toothpaste, and face creams, as well as in health, medicine and nanobiotechnology. In information and communication technologies, electronics and photonics they are used in semiconductor chips, new storage devices and displays [11]. In security they are used in sensors to detect biological threats, and in textiles they are used in protective clothing, stronger, self-cleaning or fire resistant fibers [11]. Nanomaterials are therefore very useful to the life sciences, as well as environment and human health applications, and are used as sensors for environmental monitoring, nano-drug-delivery systems, biorobotics, nanoarrays, and nanoscale implants in medicine [12,13]. Nanomaterials are thus used in many applications and are a common element of daily life. However, the rapid expansion of nanotechnology applications increases the need to increase public understanding of the risk of nanotechnology. Increased risk perceptions could lead to negative public reactions that might have a significant impact on industry [14].

The science-society interaction which focuses on public opinion toward emerging technologies has been given an increased emphasis over the past few years [15,16]. Recently, the new term “upstream engagement in nanotechnology” has been developed to diagnose upstream public engagement effects on the governance of new science and technology [17]. Public perception could have a strong impact on the progress of nanotechnology. Therefore, it is necessary to research the public perception and implication for health-related applications of nanotechnology.

Public perceptions of nanotechnology were investigated through surveys distributed to a representative sample of a national population worldwide. Studies of public opinions regarding nanotechnology have focused on the public’s knowledge and views of risks and benefits [16,18–32]. Some studies have shown a need for an understanding of the fundamental concepts of nanotechnology [33–35]. Here in Jordan, the concept of nano-education has been introduced recently to Jordanian universities and is offered to students of pharmacy, engineering, biomedical sciences, and agriculture. So far, limited research has been conducted on this important topic, and we lack understanding about public awareness of nanotechnology and its implications among the Jordanian population. Therefore, we conducted this study to evaluate Jordanian public awareness and concern about nanotechnology, nanomaterials, and nanoproducts and their implications for health, food, the environmental industry, and energy in Jordan.

The purpose of this study is: (1) to describe Jordanians awareness about nanotechnology and its numerous implications; (2) to examine the public need for relevant information about nanomaterial and nanoproducts contained in products in Jordan; (3) to explore public preference of the best route to gain understanding and knowledge of nanotechnology contained in products in Jordan.

2. Materials and Methods

2.1. Measures

A self-administered survey was used for data collection. The survey was developed based on the relevant literature [15,23,36] and contained approximately 15 different questions. Items assessing awareness of nanotechnology and the source of knowledge were extracted from the literature or generated by an expert group. Content validity and face validity of the newly developed survey were established through the evaluation of four expert researchers in this field.

The first domain of the survey included 11 questions that were designed to measure public awareness of nanotechnology, nanoproducts, nanomaterials, nanotechnology implications in industry and health-related applications of nanotechnology using a three-point Likert scale (1 = good, 2 = fair, 3 = poor) for the first seven questions and a five-point Likert scale (where 1 = strongly disagree and 5 = strongly agree) for the remaining seven questions. The second domain included three questions that were used to assess the public perspectives on nanotechnology knowledge using a five-point Likert scale (where 1 = strongly disagree and 5 = strongly agree). The last domain included a question about the
best possible source for gaining understanding about nanotechnology. The survey also includes some demographic variables, including gender, age, income, and education.

2.2. Data Collection

The study was conducted between April and May of 2020. Due to the sudden emergence of the COVID-19 pandemic and the widespread use of social media platforms in Jordan, the use of an online survey was the most appropriate method for data collection. An online survey entitled “Awareness of Nanotechnology among Consumers in Jordan” was created in Arabic using Google Forms and circulated via social media by sharing a direct link of the survey and posting an invitation on social media platforms including Facebook inviting the public to participate in the study. According to StatCounter data, Facebook is the most popular social media platform in Jordan. Participants were eligible to participate in this study if they were over 18 years, living in Jordan, and able to read and understand Arabic.

2.3. Data Analysis

Analyses were performed using SPSS Statistics version 20.0 (IBM Corporation, Armonk, NY, USA). Descriptive statistics, including frequencies and percentages, were used to summarize and describe the study variables regarding the awareness and understanding of nanotechnology and its implications. Given the small sample size, we used Fisher’s exact test instead of the Chi-square test to examine the influence of education, age, and gender on public awareness of nanotechnology and its implications. Furthermore, a bar chart was used to display the public preference of best route to gain understanding and knowledge on nanotechnology contained in products in Jordan.

3. Results

3.1. Demographic Characteristics of Respondents

In total, 248 surveys were collected. Six surveys were completed by participants under 18 years of age and therefore were excluded.

The final sample included 242 respondents. As shown in Table 1, more than half (60%) of the respondents were female and 43% had an income of less than 500 Jordanian Dinars ($705) per month. Regarding education, the vast majority of respondents (95%) had at least a bachelor’s degree or higher. The high percentage of highly educated respondents is attributable to two main reasons: the high levels of education in the Jordanian population, and the lack of knowledge about the research topic, especially among people who are less educated. In addition, over half (55%) of the respondents were between 18 and 39 years old. This high percentage of young respondents reflects the current Jordanian population, of which almost 80% is under the age of 39 [37].

3.2. Public Awareness

As shown in Table 2, most respondents (67%) reported poor knowledge and understanding of nanotechnology, nanomaterials, and nanoproducts, and almost 41.8% reported poor knowledge of its implications in food, medicine, environment, energy, in medicine, and generally. There were no significant differences in participants’ awareness of nanotechnology, nanomaterials, and nanoproducts or their use in food, medicine, environment, and energy based on the respondents’ gender, age, or education level. However, there was a significant difference in participants’ awareness of nanomaterials based on gender (p-value = 0.019). There was also a significant difference in participants’ knowledge about nanoproducts based on age (p-value = 0.043), and a significant difference in their familiarity with the nanotechnology application used in the health or medicine industry based on education level (p-value = 0.026). Finally, there was a significant difference in respondents’ familiarity with the implications of nanotechnology based on age (p-value: 0.043).
Table 1. Demographic characteristics of respondents.

| Classification                        | Frequency (Percent %) |
|---------------------------------------|-----------------------|
| Gender                                |                       |
| Male                                  | 96 (39.7)             |
| Female                                | 146 (60.3)            |
| Total                                 | 242 (100.0)           |
| Age                                   |                       |
| 18–35 years old                       | 131 (54.2)            |
| 36–55 years old                       | 102 (41.1)            |
| Above 55 years old                    | 9 (3.7)               |
| Total                                 | 242 (100.0)           |
| Education level                       |                       |
| High school and less                  | 9 (3.7)               |
| Bachelor’s degree                     | 136 (56.2)            |
| Master’s degree or diploma            | 50 (20.7)             |
| Doctorate                             | 47 (19.4)             |
| Total                                 | 242 (100.0)           |
| Average monthly household income      |                       |
| Less than 500 JD *                    | 105 (43.4)            |
| 500–1500 JD                           | 98 (40.5)             |
| More than 1500 JD                     | 39 (16.1)             |
| Total                                 | 242 (100.0)           |

* JD: Jordanian Dinar.
Table 2. The public awareness of nanotechnology according to gender, age, and education level.

|                      | General awareness of nanotechnology | How would you describe your knowledge about nanomaterial? | How would you describe your knowledge about nanoproducts? | Awareness of general nanotechnology Implications | How familiar you are you with the nanotechnology application used in food industry? | How familiar you are you with the nanotechnology application used in health or medicine industry? | How familiar you are you with the nanotechnology application used in the environment industry? |
|----------------------|------------------------------------|--------------------------------------------------------|--------------------------------------------------------|-----------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
|                      | Male | Female | p-Value | 18–35 | 35–55 | >55 | p-Value | >High School | Bachelor | Master | PhD | p-Value | Male | Female | p-Value | 18–35 | 35–55 | >55 | p-Value | >High School | Bachelor | Master | PhD | p-Value | Male | Female | p-Value | 18–35 | 35–55 | >55 | p-Value | >High School | Bachelor | Master | PhD | p-Value | Male | Female | p-Value | 18–35 | 35–55 | >55 | p-Value | >High School | Bachelor | Master | PhD | p-Value |
| How would you describe your knowledge about nanotechnology? | Good | 33 (13.6) | 13 | 20 | 0.072 | 20 | 10 | 3 | 0.253 | 1 | 14 | 11 | 7 | 0.81 |
|                      | Fair | 108 (44.6) | 51 | 57 | 2 | 57 | 49 | 2 | 2 | 59 | 27 | 20 | 20 |
|                      | Poor | 101 (41.7) | 32 | 69 | 4 | 54 | 43 | 4 | 3 | 63 | 20 | 20 | 20 |
| How would you describe your knowledge about nanomaterial? | Good | 28 (11.6) | 8 | 20 | 0.019 | 18 | 8 | 2 | 0.412 | 1 | 12 | 8 | 7 | 0.328 |
|                      | Fair | 88 (36.4) | 45 | 43 | 3 | 44 | 41 | 3 | 1 | 47 | 21 | 19 | 19 |
|                      | Poor | 126 (52.1) | 43 | 83 | 4 | 69 | 53 | 4 | 7 | 74 | 21 | 21 | 21 |
| How would you describe your knowledge about nanoproducts? | Good | 16 (6.6) | 7 | 9 | 0.253 | 10 | 3 | 3 | 0.043 | 0 | 8 | 5 | 3 | 0.905 |
|                      | Fair | 82 (33.9) | 38 | 44 | 2 | 45 | 35 | 2 | 2 | 44 | 18 | 18 | 18 |
|                      | Poor | 144 (59.5) | 51 | 93 | 4 | 75 | 64 | 4 | 7 | 84 | 27 | 26 | 26 |

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### Table 2. Cont.

| How familiar you are with the nanotechnology application related to future energy needs? | All | Gender | p-Value | Age (Year) | p-Value | Education | p-Value |
|---|---|---|---|---|---|---|---|
| | | Male | Female | | 18–35 | 35–55 | >55 | >High School | Bachelor | Master | PhD | 18–35 | 35–55 | >55 | >High School | Bachelor | Master | PhD |
| Good | 29 (12) | 15 | 14 | 0.084 | 20 | 7 | 2 | 0.228 | 1 | 18 | 5 | 5 | 0.986 |
| Fair | 79 (32.6) | 36 | 43 | | 42 | 25 | 2 | 2 | 42 | 19 | 16 |
| Poor | 134 (55.4) | 45 | 89 | | 69 | 60 | 5 | 6 | 76 | 26 | 26 |

| Awareness of nanotechnology implications in health |
|---|
| Nanotechnology is safe for human body |
| Strongly disagree | 2 (0.8) | 1 | 1 | 0.218 | 6 | 2 | 2 | 0 | 2 | 0 | 0 | 0.469 |
| Disagree | 7 (2.9) | 3 | 4 | | 34 | 24 | 2 | 0.204 | 0 | 3 | 3 | 1 |
| Neutral | 161 (66.5) | 56 | 105 | | 84 | 72 | 5 | 8 | 97 | 29 | 27 |
| Agree | 60 (24.8) | 31 | 29 | | 4 | 3 | 0 | 1 | 28 | 15 | 16 |
| Strongly agree | 10 (4.1) | 5 | 5 | | 2 | 0 | 0 | 0 | 5 | 2 | 3 |

| Nanotechnology is safe in treating cancer patients |
|---|
| Strongly disagree | 2 (0.8) | 1 | 1 | 0.591 | 2 | 0 | 0 | 0.233 | 0 | 2 | 0 | 0 | 0.819 |
| Disagree | 2 (0.8) | 0 | 2 | | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| Neutral | 134 (55.4) | 52 | 82 | | 62 | 66 | 6 | 6 | 80 | 22 | 26 |
| Agree | 85 (35.1) | 33 | 52 | | 52 | 31 | 2 | 3 | 42 | 24 | 16 |
| Strongly agree | 19 (7.9) | 10 | 9 | | 14 | 4 | 1 | 0 | 11 | 4 | 4 |

| Nanotechnology is safe in diagnosing some of human diseases |
|---|
| Strongly disagree | 3 (1.2) | 2 | 1 | 0.587 | 2 | 1 | 0 | 0 | 3 | 0 | 0 | 0.805 |
| Disagree | 9 (3.7) | 4 | 5 | | 4 | 5 | 0 | 0 | 4 | 2 | 3 |
| Neutral | 137 (56.6) | 49 | 88 | | 71 | 60 | 2 | 6 | 83 | 25 | 23 |
| Agree | 81 (33.5) | 35 | 46 | | 47 | 32 | 2 | 5 | 41 | 20 | 17 |
| Strongly agree | 12 (5.0) | 6 | 6 | | 7 | 4 | 1 | 0 | 5 | 3 | 4 |

| Nanotechnology is safe to treat addicts |
|---|
| Strongly disagree | 1 (0.4) | 0 | 1 | 0.924 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0.939 |
| Disagree | 3 (1.2) | 1 | 2 | | 1 | 2 | 0 | 0 | 1 | 1 | 1 |
| Neutral | 143 (55.1) | 60 | 83 | | 69 | 65 | 6 | 6 | 81 | 25 | 31 |
| Agree | 82 (33.9) | 30 | 52 | | 50 | 30 | 2 | 3 | 44 | 21 | 14 |
| Strongly agree | 13 (5.4) | 5 | 8 | | 10 | 2 | 1 | 0 | 9 | 3 | 1 |
3.3. Public Outreach

As shown in Table 3, at least 83.8% revealed the need for continued outreach of information. Almost 76.9% reported a need for better communication about the risks of nanoproducts and 77.1% reported that promotion and education with regard to nanoproducts are necessary.

Table 3. The respondents’ perspectives toward nanotechnology knowledge.

| Classification                                                                 | Strongly Agree | Agree    | Neutral | Disagree | Strongly Disagree |
|--------------------------------------------------------------------------------|----------------|----------|---------|----------|-------------------|
| More relevant information regarding nanotechnology is needed.                  | 103 (41.5)     | 105 (42.3)| 36 (14.5)| 3 (1.2)  | 1 (0.4)           |
| Public need for developing appropriate communication about the risks of nanoproducts. | 98 (39.5)      | 92 (37.1) | 53 (21.4)| 2 (0.8)  | 3 (1.2)           |
| Promotion and education on nanotechnology and nanoproducts are necessary.      | 91 (36.7)      | 106 (42.7)| 47 (19.0)| 2 (0.8)  | 2 (0.8)           |

3.4. Routes to Gain Information about Nanotechnology and Its Implications

As shown on Figure 1, research institutions, media and universities are the most preferable methods by respondents to gain new information about nanotechnology and its various implications.

![Figure 1. Public preference of best route to gain understanding and knowledge on nanotechnology contained in products.](image-url)
4. Discussion

This study aimed to evaluate Jordanian public awareness and concern about nanotechnology, nanomaterials, and nanoproducts, and their implications. It also aimed to verify the public need for education and relevant information about nanomaterials and nanoproducts contained in products in Jordan, and to understand public concerns with regard to potential problems that may be caused by nanotechnology. Our findings showed that the public as represented by the sample in this survey is generally poorly informed about nanotechnology and its implications. This could be the main reason for the non-significant difference among respondents regarding the variables included. In this study, we surveyed public awareness of nanotechnology and the need for education about nanotechnologies. Our findings are consistent with earlier studies that have also found that the public had very little knowledge or awareness of nanotechnology [1,5,6,29,38–42]. Overall, 67% of participants in this study reported poor knowledge of nanotechnology, compared to 79.8% in Iran [43], 49% in America [44] and 23% in Germany [45]. Our findings also revealed that variables such as gender, education and age were all significantly relevant to perspectives on nanotechnology knowledge. Our finding is similar to the results of several valuable studies done in Iran [43]. Approximately 81% of participants in our study reported that “research institutions” are the suitable routes of information on nanotechnology, nanomaterials, or nanoproducts contained in products in Jordan. In addition, the increasing awareness of nanotechnology can be led by courses and workshops offered at educational institutions such as schools and universities. Experimental designs can also be used to provide participants with more information about nanotechnology [46].

The majority of respondents in our study were slightly or moderately afraid of potential problems that nanotechnology may cause, and no significant differences were found regarding to how afraid the public are of the potential problems that may be caused by nanotechnology. This could be due to the public’s modest knowledge about nanotechnology. Therefore, government agencies may be motivated to perceive and implement knowledge about nanotechnology and its implications for health in particular.

5. Implications

Considering the large percentage of participants with poor knowledge about nanotechnology but mild fears about it, it can be concluded that there are many informative actions to be taken to inform the general public of Jordan on the nature and potential risks and benefits of nanotechnology. Our findings can be used to develop strategies that help Jordanians to understand nanotechnology and to enable them to differentiate between the different fields of its application. An educational system should be established to address public expectations and concerns. Moreover, a safety assessment system must be established, and its results should be handled by a professional team of experts so that they can be disseminated to the public. Therefore, governmental agencies and experts in the field of nanotechnology from universities, research institutes, industry, and non-governmental organizations (NGOs) must provide accurate information on nanotechnologies and their applications to the public [46].

6. Limitations

First, related to the small sample size, we suggest that this study should be regarded more as a feasibility study of a general community population in Jordan. Related to the limited number of participants, this study does not represent the true population, and therefore further research is needed to clearly identify how the public perceives nanotechnology, as well as the risks and benefits of the technology by utilizing a larger representative sample.

Second, the survey used in this study was not previously validated; additionally, because of the relatively small number of responses, there might have been a selection bias among our participants. For example, some participants who refused to participate added a note that because they were not knowledgeable enough about nanotechnology they have
declined the study’s invitation and eventually the survey was mainly completed by highly educated people. Finally, this is more of an initial study, and further research with a more rigorous methodology is needed to support our findings. This is important since some of the answers from respondents can be perceived as individual and may reflect feelings rather than actual knowledge or level of information.

7. Conclusions

While nanotechnology has shown promising applications in several bio-industrial and medical fields, further studies are needed to obtain an accurate overview of the public’s awareness, understanding and attitudes toward nanotechnology. Our findings show that more than half of the respondents have a very low awareness with regards to nanotechnology and its various implications. Additionally, respondents showed interest in learning more about nanotechnology and its implications, preferring several sources of information such as media, universities and research institutions. This suggests the need for more efforts to increase public awareness of this field so as to avoid unwanted counterattack. Both researchers and governmental bodies need better engagement with their industrial partners, the media and consumers to increase their understanding of this new field of technology.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare that they have no conflict of interest.

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