The Needs to Regulate Nanomaterials and Nano Products in Malaysia: Stakeholders, Industry, and Consumer Perspectives

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ABSTRACT

Nanomaterials and nano products have transitioned from the laboratory to market shelves and e-commerce websites, reaching consumers and being released into the environment. Nanomaterials' unique properties make them a darling to the industry. They have been applied across various industries, including nanosilver in textiles, nanogold in cosmetics, cancer treatment, coating, sensors, packaging, and more. Despite the unique properties of nanomaterials, research shows that some nanomaterials and nanoproducts may cause risks to human health and the environment. Given the increasing number of nanomaterials and nano products, there is are need to regulate. Some countries regulate nano products by using the prevailing laws on chemicals, cosmetics, food, and pesticides. However, the unique properties of nano products do not seem to fit in the prevailing law. Recently, some countries have even started to ban certain nanomaterials from the market. This paper discusses the need to regulate nanomaterials and nano products in Malaysia based on interviews with selected stakeholders, industry, and consumers. This paper starts with an introduction to nanomaterials and nano products, a discussion on the risk of nanomaterials and nano products, Malaysia's current state in managing nanomaterials and nano products, and finally, findings on the needs for regulations from the perspective of stakeholders, industry, and consumers.

Keywords: nanomaterial regulations, nano product regulations, nanotechnology, nano claim, nano label

1.0 INTRODUCTION

'*Logic will take you from A to B. Imagination will take you everywhere'* – Albert Einstein. On January 2000, President Clinton in his speech while unveiling the National Nanotechnology Institute (NNI) asked his audience to imagine '*materials with 10 times the strength of steel and only a fraction of the weight; shrinking all the information at the Library of Congress into a device the size of a sugar cube; detecting cancerous tumors that are only a few cells in size*.' This question invites the audience to imagine the possible application of nanotechnology.

Nobel Laureate Richard Smalley defined nanotechnology as the art and science of building stuff that does stuff at the nanometer scale. Nanotechnology is not something new. It has been with us for the last billion years in nature, or known as 'natural nanotechnology'. Natural nanotechnology can be found in gecko toes and spider webs. Geckos have a remarkable ability to run at any orientation on just about any smooth or rough, wet or dry, clean or dirty surface because of the million nano-size hairs found on their toes. A spider web can survive multiple tears and wind, yet it is very thin because of protein in nanoscale that gives strength to the web.

For this paper, the term nanotechnology is generally divided into nanomaterials and nano products. Nanomaterials refer to chemicals in nano-sized or, also known as raw or unfinished products, for example, nano silver in powder or liquid. Nano products refer to products that incorporate nanomaterials or finish products. For example, nano socks that incorporate nano silver.

Malaysia has put nanotechnology as its priority. The former prime minister, Datuk Seri Najib Razak, has acknowledged this in his speech that "*it is important for Malaysia not to be left behind in the field of nanotechnology and we have decided to give it importance*." The key factor of this scientific breakthrough is the manipulation of matter at the nanometer scale, which is extremely small. This comma, for instance, spans about half a million nanometers. Nanotechnology has produced wondrous nano products by incorporating unique properties of nanomaterials, making the product cheaper, lighter, efficient, and longer-lasting. Main nano product inventory like Statnano, Project on Emerging Nanotechnologies, Nanodatabase, and R-Nano.fr in **Figure 1** display thousands of nano products placed on the market, and the number is increasing. Based on the inventory, nano product is commonly found in the products of personal care, cosmetics, clothing, sporting goods, electric and electronic, food, and many more. **Table 1** shows the examples of nano products, their nanomaterials, and applications.

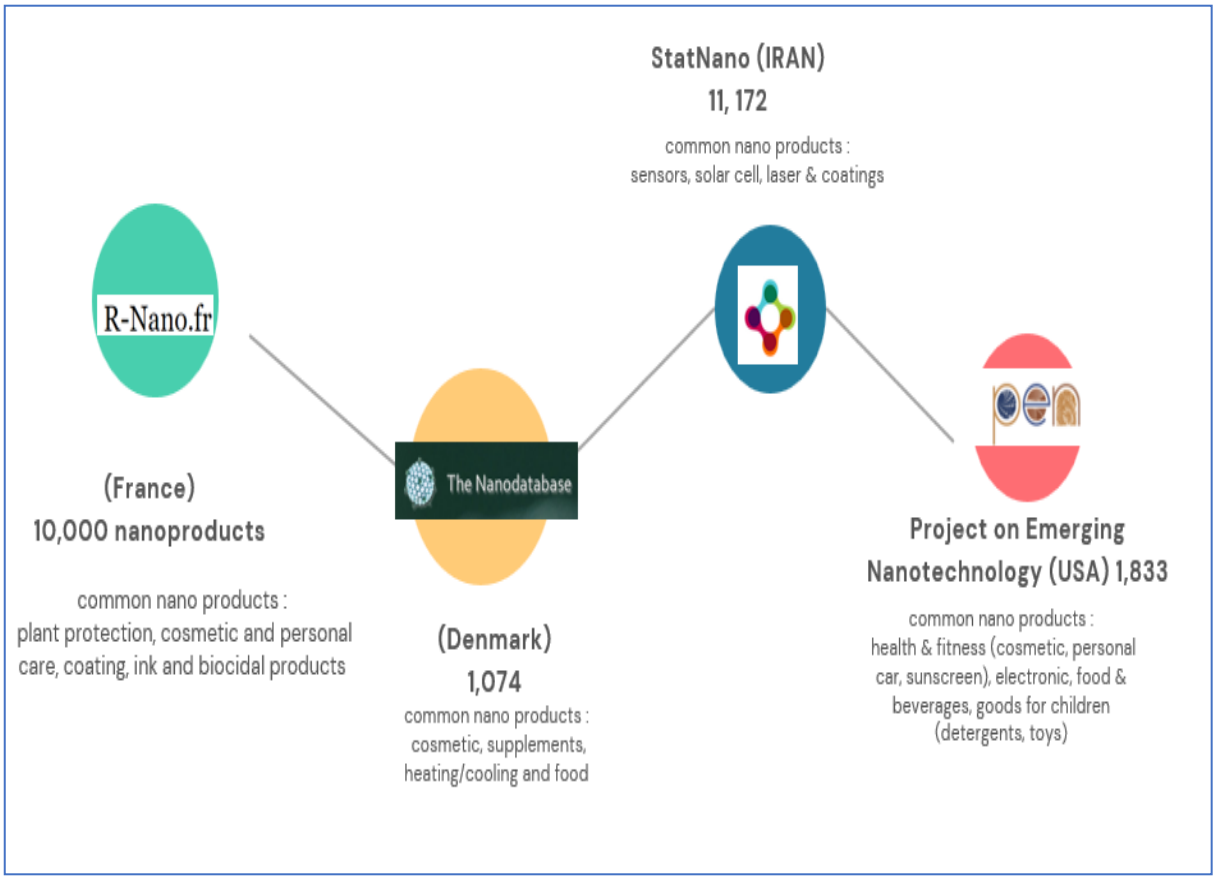


Figure 1: The Total Number of Nano Products from Different Database.

Source: Author's Analysis

Table 1: Examples of Nano Product, Nanomaterial, and Application

No.	Nano Product	Nanomaterial	Application
1.	Nanocosmetics	Silver, Gold, Titanium, Zinc Nanoparticles	UV filters, moisturizers, hair care, skincare
2.	Silver Nanocomposites	Silver Nanoparticles	Antibacterial, antifungal, antiviral, anti-inflammatory
3.	Water Treatment Adsorbents	Carbon Nanotubes, Graphene, Metal Oxides	Pollutant removal in water treatment
4.	Biomedical Implants	Carbon Nanotubes, Graphene, Fullerenes	Tissue engineering, drug delivery
5.	Supercapacitors and	ZnO Nanostructures	Energy storage, solar

	Batteries		cells, supercapacitors
6.	Nanofilms and Coatings	Various Nanoparticles	Enhanced physical and chemical properties
7.	Nanomaterial Adsorbents	Metal Oxides, Carbon Nanotubes	Environmental treatment, pollutant adsorption
8.	Nanomagnets	Bulk Nanostructured Materials	Magnetic applications, data storage

Source: Author's analysis

2.0 PROBLEM STATEMENT

Nanomaterials are used in various industries, including medical, pharmaceutical, food, and electronics, with the potential to impact human health and the environment (Chávez-Hernández, 2024). Nanomaterials possess unique properties that may pose risks to human health due to their small size and increased surface area.

2.1 Risk to humans

Nanomaterials can interact with biological systems in ways not seen before, raising concerns about their potential adverse effects on human health (Shajar, 2023). The biggest concern is that this nanoparticle could be inhaled, absorbed through the skin, or ingested. Most nano-sized spherical solid materials will easily enter the lungs and reach the alveoli (Hoet, 2014).

Inhaled particles can have two major effects on the human body. Their primary toxic effect is to induce inflammation in the respiratory tract, causing tissue damage and subsequent systemic effects (C-W, 2004). Second, transport through the bloodstream to other vital organs or tissues of the body may result in cardiovascular and other extra-pulmonary effects. For example, nanosilver can go places in the body that larger silver particles cannot, and it may be small enough to enter cells or cross the blood–brain barrier (Nemmar, 2002).

Workers and researchers usually wear gloves while handling the nanomaterials. While the gloves can minimize dermal exposure, airborne clumps of material can lead to exposure of less well-protected parts of the skin (Maynard, 2004). The Institute of Occupational Medicine, to the UK's Health and Safety Executive, concludes that there is little evidence to suggest that the exposure of workers arising from the production of nanoparticles has been adequately assessed. (Executive, 2004)

Exposure to nanomaterials during manufacturing or use as consumer products is not well investigated, leading to a lack of information on their effects compared to macroscale materials (Riaz, 2021). Occupational exposure studies have shown that workers handling nanomaterials experience significant respiratory and dermal exposures, indicating potential health risks (Nasirzadeh, 2024).

Apart from academics' findings on the risk, real-life examples of the risk started to surface. On 19th August 2009, seven young Chinese women suffered permanent lung damage, and two of them died after working for months without proper protection in a paint factory using nanoparticles (Lyn, 2009). Particles around 30 nanometers in diameter were found in lung fluid and tissue, and this incident triggered the debate over the environmental health effects of nanotechnology. Other experts are skeptical as to whether nanoparticles are actually to blame, but the incident has triggered discussions. Andrew Maynard, a nanotechnology expert at the Woodrow Wilson International Center for Scholars in Washington, responding to the incident, said that it raises the bar for doing appropriate research as fast as possible to find out where the dangers might lie when working with nanomaterials (Gilbert, 2009).

2.2 Risk to the environment

Risk to the environment occurs when nanomaterials are released into the environment. For example, silver compounds in textiles and cosmetics will end up in wastewater treatment plants. Nanosilver impregnated into consumer products and coatings will slowly, through laundering, be abraded from its substrate material at

varying volumes and over varying periods, depending on concentrations in the material and the strength with which it is bonded (Seltenrich, 2013). In consumer textiles, the industry standard is for the antimicrobial effect to persist over at least 50 washes, although some research suggests nanosilver can leach from certain products within the first few washes. Due to the widespread and high use of nanosilver, it will eventually be released into our lakes and streams from municipal and industrial wastewater. This could put aquatic organisms at risk of toxic effects. Nanosilver is acutely toxic to bacteria, algae, crustaceans, and fish. (Benn TM, 2008)

Nanosilver has the possibility of killing organisms in the water, which is important for the ecosystem. A 2010 report identified nanosilver as one of the fifteen emerging issues that could threaten biological diversity (Sutherland, 2010). Nanosilver can enter the aquatic environment through many routes, e.g., washing of wounds treated with nanosilver plasters, washing machines equipped with nanosilver to purify clothing, and laundering of treated fabrics.

Nanomaterials have the potential to impact the environment, but there are unanswered questions about their long-term effects on organisms and human health (Ramanan, 2011). The widespread application of nanomaterials confers the potential for environmental release and subsequent human exposure, highlighting the need to understand their behavior in the environment and their effects on ecosystems.

The rapid increase in the use of nanomaterials in various industries raises concerns about their potential health and environmental risks. While nanomaterials offer new product possibilities, their impact on human health and the environment must be carefully considered.Proper risk management strategies, workplace standards, and regulatory guidelines are crucial to ensure the safe handling and disposal of nanomaterials and protect human health and the environment.

However, it is important to note that the current knowledge concerning the health effects of exposure to nanoparticles is limited, and more research is needed to understand and address the potential risks associated with nanomaterials.

3.0 METHODOLOGY

This paper adopts a mixed-methods approach, integrating qualitative and quantitative research methods to get a comprehensive understanding of the perspectives of various stakeholders, industry, and consumers regarding the regulation of nanomaterials and nano products in Malaysia.

The targeted samples are, first, r**egulatory bodies consisting of r**epresentatives from government agencies responsible for environmental protection, health, safety, and regulations. Second, **the industry stakeholders, which consist of m**anufacturers, researchers, and businesses involved in the production and distribution of nanomaterials and nano products. Next, c**onsumers** who use nano products, including general consumers who are non-users.

Semi-structured interviews are conducted with representatives from regulatory bodies and industry stakeholders. This qualitative method will allow for in-depth exploration of their perspectives, challenges, and recommendations regarding regulation. A structured questionnaire was developed to gather quantitative data from industry and consumers. The survey aims to assess awareness, perceptions, and attitudes towards the regulation of nanomaterials and nano products. The survey was analysed to identify frequency, trends, and correlations.

4.0 FINDINGS

4.1 Malaysia's Current State In Managing Nanomaterials or Nano Products

4.1.1 Stakeholders

The main stakeholder is the National Nanotechnology Centre (NNC) under the auspicious of the Ministry of Science, Technology and Innovation (MOSTI). NNC is supported by other government agencies and government-linked companies, as shown in **Figure 2**.

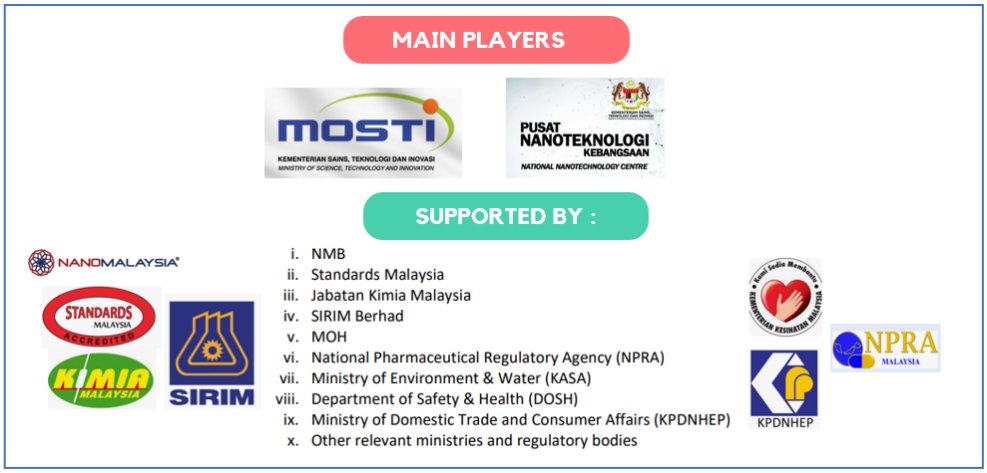


Figure 2: Malaysia's Stakeholders for Nanotechnology.

Source: Malaysian Government's National Nanotechnology Policy & Strategy 2021–2030, published by the Ministry of Science, Technology and Innovation (MOSTI/MASTIC)

The NNC has come out with the National Nanotechnology Policy and Strategy 2021-2030, among others, to strengthen the standard, safety, and regulation of nanomaterials and nano products in Malaysia. **Figure 3** is the relevant policy strategy, which envisioned that Malaysia would develop a database to record the nano products in Malaysia, which is needed not only for future risk assessment and risk management but also to facilitate networking between the nanomaterials industry and manufacturers in Malaysia.

National Nanotechnology Policy & Strategy 2021-2030

STRATEGIC THRUST 4: STRENGTHENING STANDARD, SAFETY AND REGULATION

ISSUES & CHALLENGES			
1. Lack of awareness on standards, safety, and regulation specific for nano.			
STRATEGY			
4.1 Promoting the importance of standard and safety among industries towards increasing the value of nanotechnology products.			
INITIATIVES	**SHORT-TERM (2021-2022)**	**MEDIUM-TERM (2023-2025)**	**LONG-TERM (2026-2030)**
4.1.1 Developing a comprehensive nano database as an inventory of local nano-based products as well as reference on nano safety, standard & regulation.	A comprehensive nano database with inventory of at least 100 local nano products.	Inventory of at least 200 local nano products. Database expanded to nano-products in ASEAN markets.	Inventory of at least 300 local nano products.

Figure 3: Strategy to Strengthen Standard, Safety and Regulation

Source: Malaysian Government's *National Nanotechnology Policy & Strategy 2021–2030*, published by the Ministry of Science, Technology and Innovation (MOSTI/MASTIC)

In August 2023, the NNC launched the Nanosafety Referral System (NRS) to display the products verified as nano, which are available in the Malaysian market. To date, there are 358 verified nano products registered in the NRS, as shown in **Figure 4**. This system is important to consumers to find out the verified nano product instead of a product that simply claims to be a nano product.

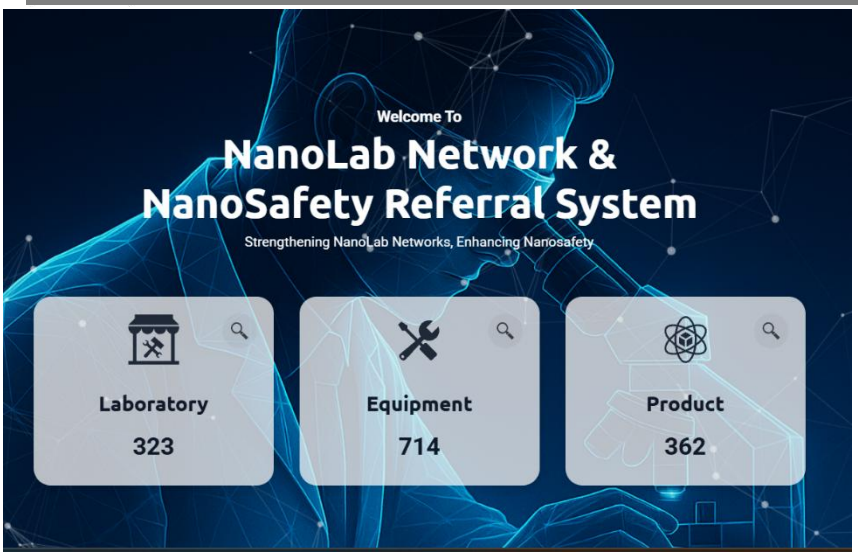


Figure 4: Nanosafety Referral System (NRS)

Source: https://nalnrs.mosti.gov.my/

The top two categories of products are skincare 56, followed by surface coating 48. (MOSTI, 2025).

4.1.2. Regulatory Framework

In Malaysia, the regulatory framework for nanomaterials and nano products is still in its nascent stages and lacks specific laws tailored to the unique properties and risks associated with nanomaterials and nano products.

Nanofood

Nanofood in Malaysia is currently regulated under the same framework as conventional food through the Food Act 1983, which does not account for the unique properties of engineered nanomaterials (ENMs). There is a call for amendments to the existing food safety framework to incorporate specific provisions for nanotechnology, based on the precautionary principle, to better protect consumers from potential risks (Hasmin, 2024).

Occupational Safety

There are no specific laws or statutory regulations governing the application of nanotechnology in the workplace. However, the Department of Occupational Safety and Health (DOSH) has published Guidelines On The Control and Safe Handling of Nanomaterials (Ismail, 2019). This guideline is a subsidiary legislation made under the Occupational Safety and Health Act 1994, which provides recommendations for workplace safety. (Health, 2018)

Nanocosmetics

The usage of nanomaterials in cosmetics is allowed as colorants and UV filters in Guidelines for Control of Cosmetic Products in Malaysia (2nd Edition), effective from August 2022. The guideline, however, has no provisions for nano labelling to inform consumers about the presence of nanomaterials in cosmetic products. (Basir, 2024).

Malaysia is in the process of formulating safety standards relevant to nanotechnology, but as of now, there are no comprehensive laws specifically addressing the broad spectrum of nanotechnology applications (Karim, 2015). In summary, while there are some guidelines and frameworks in place, Malaysia lacks comprehensive and specific laws governing nanomaterials and nano products, highlighting the need for regulatory reforms to address the unique challenges posed by nanotechnology.

5. FINDINGS ON THE NEED TO REGULATE NANOMATERIALS AND NANO PRODUCTS

5.1 Stakeholders

5.1.1. National Nanotechnology Center (NNC) MOSTI

While emphasizing that the development of regulation is something which will only happen in the next five years, the NNC believes that there is a need to regulate nanomaterials and nano products in Malaysia on the basis of three main reasons.

Firstly, to protect Malaysia from becoming the dumping site of nano products rejected from other countries. Risk assessment on the product safety must be conducted before the product is allowed to enter Malaysia. This is very much relevant as there are countries that have started to ban certain nanomaterials. Secondly, to protect workers. Workers here not only refer to factory workers but also researchers at the university. A registry is needed to identify the frequently used nanomaterials in the product to manage the handling and the risk. Thirdly, to protect consumers against the adverse effects of nano products and to protect consumers against fraud from products that claim to be nano when in fact it is not.

5.1.2 NanoMalaysiaBerhad

NanoMalaysia Berhad believes that there is a need to impose registration as it would raise consumer confidence to buy nano products and as a mechanism to ensure only genuine nano products are commercialized.

5.1.3 Ministry of Health: Standard Codex Division

The need for regulation has not arisen yet. Nano products that will cause injury are currently governed by Section 13 of the Food Act 1983. As regards food nano claims, section 14 governs the prohibition against the sale of food not of the nature, substance, or quality demanded. This would mean that the seller should not claim that the food is nanofood when in fact, it is not.

5.1.4 Ministry of Health: National Pharmaceutical Regulatory Agency (NPRA)

The need for regulation has not arisen yet as the NPRA registers a product based on quality, safety, and efficacy, which is said to cover all products, including nano products.

5.1.5 Department of Islamic Development Malaysia (Halal Hub)

The need for regulation would depend on the Ministry of Health because the department is subject to the law under the Ministry of Health. The need will arise if there’s evidence that a nano product is injurious to health, or where there’s a fatwa about it, or consumer demand for it.

5.2 Industry Perspective

Based on the NRS, there are more than 100 organisations that are involved in manufacturing nanomaterials or nano products. However, due to the limitation of time and resources, as well as no response from several companies, only three companies were interviewed on the needs for regulation. The three companies interviewed are listed in the NRS.

A survey of the company is conducted through a guided questionnaire to observe the company's involvement in nanotechnology, the need for regulation, and their concerns should regulation take place. The companies interviewed are small and medium enterprises that are involved in the beverage industry, cosmetic industry, and textile industry, producing below than 15 products, and are involved in export and import activity.

The needs for regulation

Company A agrees there is a need for a regulation that can protect their product, as currently they have invested

money in the development of nanotechnology, but they have to compete with other companies that simply claim their product as nano. Also, industry needs a regulation to ensure safe handling of and transparency of nanomaterials. The company knows that some companies to whom it supplies nanomaterials are being secretive about the presence of nanomaterials by not mentioning it on the product label. It also raised concerns about the mishandled of nanomaterials. The example given was, nanomaterials, if used correctly, should give the effect of whitening skin, but if used incorrectly, will not whiten but darken skin. Company B agrees that there is a need for a regulation that could certify genuine nano products, give a label like the Halal logo to gain customers' confidence. Only those proven to use safe nanomaterials must get the certificate. Customers are not confident in buying their product because many products use nano words, making it of no value and just as market hype. Company C does not agree with any need for regulation.

The concerns

All companies agreed that trade secret, cost, trade barrier, and compliance processes are their main concerns. Should regulation, for example in the form of mandatory registration, be implemented on them, they need a suitable time frame and incentive as a driving factor for them to cooperate to comply with the new regulation. Trade secret is their main concern as nanotechnology is a competitive business.

5.3 Consumer Perspective

A survey of consumers was conducted using questionnaires. The questionnaire was distributed to 300 consumers through google forms, handout, face-to-face, phone call, email, and postage. The respondents are from Peninsular Malaysia, Sabah, and Sarawak. The questionnaire was divided into three sections, starting from Part 1 on general information, Part 2 on the nano product, and Part 3 on the opinion.

Part 1 records the gender, age, and residence of the respondents. The finding shows that the respondents are fairly divided between male and female, with females (57%) and males (43%). Most of the respondents are between 21-30 years old (42%), followed by 13-20 years old (40%), 31-40 years old (13%), and 31 years old and above (5%). 85% of the respondents resided in Peninsula Malaysia, while the remaining 15% were from Sabah and Sarawak.

Part 2 ascertains the respondent's knowledge about nano products, the respondent's purchasing attitude towards nano products, nano products seen by the respondent in the market, and the respondent's concerns about nano products.

With regards to knowledge about nano products, 73% of respondents know about nano products, while the remaining 27% didn’t know about nano products.

With regards to purchasing experience, 50.3% responded that they never bought any nano product, while 49.7% responded that they had bought a nano product. Hence, the purchasing experience among respondents is fairly divided in half. Half of the respondent has experience buying nano products while the other half have no experience in buying nano products.

Four factors were listed to assess respondents' purchasing attitude, which are place, price, promotion, and the place of the nano product. ‘Place’ means the product is available and accessible. ‘Promotion’ means advertisement, market trend, and market hype. ‘Price’ means the price is cheap and reasonable. ‘Product’ means acceptable quality and brand. 45% choose ‘Product’ as first factor, ‘Price’ as second factor (34%), ‘Promotion’ as third factor (16%), and ‘Place’ as fourth factor (5%). This means that the respondent will buy a nano product if the nano product is of acceptable quality and brand.

For nano product seen in the market, majority of the respondents have seen ‘cosmetic’ nano product (81%), followed by ‘personal care’ (45%), ‘laundry and detergent’ (31%), ‘supplement and vitamin’ (30%), ‘food and beverage’ (24%), ‘home appliances’ (23%), ‘clothing and fabric’ (17.8%), ‘garden appliances (17.1%), ‘goods for children’ (13.8%) and ‘other’ (9.1%). This means that nano products that dominate the Malaysian market are cosmetics, personal care and laundry, and detergents. The respondents are allowed to tick more than one nano product seen in the market, hence explaining the various percentages. When it comes to the issue of

concern, respondents were asked to indicate what their concern was about the nano product between 'safety' and 'quality'. 'Safety' means respondents are not sure whether the nano product is safe or not. 'Quality' means respondents are not sure if it is a genuine nano product or not. The result is majority of respondents indicate 'safety' as the first concern (67%) and 'quality' as the second concern (33%). This means that the safety of the nano product is the main concern of the respondent in buying the nano product.

For Part 3 of the opinion section, eight questions were asked. Table 2 below presents the results of a survey regarding public opinions on the regulation and labelling of nano products. The survey consists of eight questions, and respondents answered with either "Yes" or "No." **Table 2** below shows the percentage of people who agreed "Yes" or disagreed "No" for each question.

No	Question	Yes (%)	No (%)
1	Do you agree that a nano product must be proven to be genuine (did use nanotechnology / did contain nanomaterials) first, before allowing it to be placed on the market?	93.8	6.2
2	Do you agree that a nano product must be proven to be safe for consumers first, before allowing it to be placed in the market?	94.8	5.2
3	Do you agree that nano products and nanomaterials must be proven to be safe for the environment first, before allowing them to be placed in the market?	94.4	5.6
4	Do you agree that nano products must be labeled like Halal products?	90.6	9.4
5	Do you agree that only a nano product that is proven to be genuine and safe is labeled?	85	15
6	Do you agree that the labeling of nano products will help you to make an informed choice?	92.7	7.3
7	I prefer a nano product with a label	88.9	11.1
8	If the government imposes a mandatory registration for nanomaterials and nano products, will you support it?	92	8

Table 2: Consumers' opinions. Author's finding.

The table presents the results of a survey that measured public opinions on the regulation and labelling of nano products and nanomaterials. Overall, the responses indicate strong public support for strict regulatory measures before such products are introduced to the market. A significant majority (93.8%) agree that nano products should first be proven genuine, meaning they truly contain nanomaterials, before being sold. Even higher percentages of respondents believe these products must be proven safe for consumers (94.8%) and the environment (94.4%) prior to market placement.

Additionally, there is considerable support for the labelling of nano products. About 90.6% of respondents agree that nano products should be labelled similarly to Halal products. Moreover, 92.7% believe that such labelling helps consumers make informed choices, and 88.9% express a preference for nano products that are labelled. However, a slightly lower percentage (85%) agree that only nano products proven to be both genuine and safe should carry a label.

Finally, the idea of government-imposed mandatory registration of nanomaterials and nano products is also well-received, with 92% of respondents supporting this measure. In summary, the findings reflect a strong public desire for transparency, safety assurance, and regulatory oversight in the development and distribution of nano products and nanomaterials.

6.0 CONCLUSION

Malaysia has joined the race to excel in the advancement of nanomaterials and nano products. The global market indicates the rising number of nanoproducts originating from Malaysia, which stirs concern about the effect on Malaysian consumers and the environment. Unlike China, there is no real case scenario affecting customers or

workers in Malaysia. However, given the potential risk, there is a need to manage, minimize the effects and regulate nano products and nanomaterials in line with the precautionary principle.

Currently, Malaysia has established the NNC as a key stakeholder to manage nanomaterials and nano products, which shows the government's commitment to managing these. It can be seen through the National Nanotechnology Policy and Strategy 2021-2030 and the development of a website known as the Nanosafety Referral System. It is important to note that the website is operating voluntarily, which may not truly reflect the exact number of nano products in Malaysia. Although it provides a valuable platform for customers to verify that products are genuinely 'nano', it does not ensure that the products are safe. Therefore, it is recommended that nanoproducts or nanomaterials undergo a safety assessment or be certified as safe before verification.

The regulations for nanoproducts and nanomaterials are currently in a piecemeal nature and are generally governed under the Food Act 1983, Guidelines on the Control and Safe Handling of Nanomaterials, and Guidelines for Control of Cosmetic Products in Malaysia. The legislation and subsidiary legislations govern nano products and nanomaterials for food, workers, and cosmetics. It can be deduced that nano products and nanomaterials used in food, worker safety, and cosmetics are specifically regulated by legislation and subsidiary regulation, as these categories are considered high-risk and require greater regulatory attention.

Some countries have started to ban certain nanomaterials in their country. When the manufacturer can no longer sell that product in that country, they will find another country to place the product. This is the concern raised by NNC, where it is afraid that Malaysia will be a dumping site for the banned nanomaterials and nano products from other countries.

The support for better and more effective regulation is also echoed by the industry, even though the support comes with some concerns and a demand for incentives. The need to regulate nanomaterials and nano products stems from different perspectives. If the stakeholders need the regulation to protect customers, workers, and the environment, the industry needs the regulation for a conducive market environment for their nanomaterials and nano products to thrive. This is because, when the government initiates the NRS, it safeguards their products and minimizes unnecessary competition from products that simply claim as nano.

Above all, how far nano products will last in the market is very much dependent on the customers' acceptance. The survey results highlight a strong public demand for the need to regulate nano products and nanomaterials, emphasizing the need for clear safety standards and verification before placing them on the market, and transparent labeling for the products that are already available in the market. Although the NRS meets one of the identified needs, the remaining two still require further action.

7.0 RECOMMENDATION

To enhance the regulatory framework, Malaysia should transition the voluntary Nanosafety Referral System into a mandatory declaration and traceability registry for all nanomaterials and nano products. Making this declaration legally compulsory will ensure that the government can fully track the lifecycle of engineered nanomaterials from manufacturing to disposal, facilitating rapid product recalls if specific particles are later proven hazardous.

Furthermore, the National Nanotechnology Centre should expand its current focus beyond cosmetics and personal care to establish specific, enforceable safety standards for high-risk applications in consumer textiles, surface coatings, agricultural pesticides, and domestic water treatment adsorbents.

Future academic research should broaden the empirical scope by conducting large-scale quantitative surveys that incorporate multinational corporations alongside small and medium enterprises to better represent the industry. Future research must also conduct localized environmental impact assessments and workplace exposure monitoring within Malaysian factories to generate domestic data on how nanomaterials interact with local aquatic ecosystems and waste treatment facilities. Finally, the relevant ministries should introduce transparent, standardized nano-labelling regulations, similar to trusted certification marks, to prevent fraudulent marketing

hype, protect consumers against deceptive claims, and empower the public to make fully informed purchasing decisions.

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