

# Nanotechnology in Malaysia: A qualitative study about the current occupational health and safety issues

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## ABSTRACT

In Malaysia, nanotechnology (NT) entered the nation, infrastructural advanced technology since 2001. A careful description of the health monitoring and health and safety audit protocol is important for creating a consistent roadmap towards feasible health and safety risk management. In 2018 Department of Occupational Safety and Health (DOSH) presented the nano-material guideline for control and safe handling that contains only some of the main concepts of safe handling of nanomaterials (NMs) at related workplaces. Nevertheless, how this guideline should be implemented in the workplace still remains in the shadow of ambiguity, which is a result of the lack of policy framework for governance and execution of this guideline. Hence, this study concentrates on the current health and safety management situation, with special emphasis on health surveillance and health and safety audits in both academia and industrial NT workplaces. To this end, four key objectives are chosen by the authors of this research to be discussed and investigated: i) Current health monitoring procedure for nano-workers in different nano work environments in Malaysia, ii) Current situation of implementing health and safety audit procedure in nano workplaces in Malaysia, iii) Current health risk assessment and management concerns for nano-workers, and iv) Current health and safety assessment procedure of nano-workers and NT governing agencies opinions about these issues. Furthermore, the IRGC framework is employed to address these objectives.

In the present study, the qualitative approach by using semi-structured interviews and also document analysis procedures conducted. The data then analyzed through the thematic analysis process.

The findings of this study indicate that: i) NT workplaces of today's Malaysia are suffering from a misunderstanding of the definition of health risk in NT workplaces, which requires enlightenment by providing a comprehensive policy for this matter, ii) There is indeed an immense need for a specialized training program with a focus on handling and utilization of NMs, iii) At the moment consolidated health risk records NT workplaces are missing, iv) There is a serious need to formulate and ease the communication complications between NT workplaces and the governing agency in Malaysia.

In short, the current health and risk management procedure for nano-workers in Malaysia is unclear; as yet, no defined framework and policy proposed for the DOSH's recently published guideline. Presenting a specified procedure for safe handling and utilizing of NMs in the workplaces, developing training programs to improve the workers' knowledge about the occupational hazardous impact of working with NMs, outlining a clear protocol for nano-workers health records, and finally improving the communication between different NT involved parties are the main suggestions of this study. The field of NT came a long way in Malaysia, yet there is much remained to be discovered and developed, alongside the rest of the world.

## Keywords:

nanotechnology, health and safety management, policy, DOSH guideline, Malaysia

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## Introduction

During the 1950s, the backbone of modern nanotechnology (NT) came into being, which was then followed by groundbreaking studies carried out by the Nobel Prize winner Richard Feynman in physics in 1965 (Hulla et al., 2015). In general

terms, NT refers to the atomic structure of 1 to 100 nm materials with new characteristics that include new approaches to scientific disciplines (EU, 2011). As a result, the small size of nanomaterials (NMs) may exhibit different behaviors compared with the same bulk of usual

chemical material, e.g., melting point, permeability, etc. (Hougaard et al. 2015).

NT is rapidly intervening with all different angles of human lives, which creates extreme demands to investigate this rather unexplored territory of science with an extra magnifier. There are valuable assessments and studies which reported the hazardous impact of working with engineered NMs (Buitrago et al., 2019; Groso, et al., 2016; Voidazan, et al., 2018). The physicochemical size of NMs allows them to easily pass through the natural barriers (e.g., skin, respiratory system) of the human body and sub sequentially interfering with the different organ's function in a variety of ways (e.g., bloodstream, lung, digestion systems) (Xiaoming et al., 2014; Oberdörster et al., 2005; Ryman-Rasmussen et al., 2006; Savolainen et al., 2010). Pulmonary toxicity, cardiovascular disease, reproductive toxicity, and cancer, already reported as a consequence of inhaling these particles (Stone et al., 2017; Landsiedel et al., 2014). Traces of these particles are detected in the bloodstream and the lymphatic system, which provides them the possibility to outreach to the other crucial organs and tissues, such as the brain, liver, etc. (Pietrojusti et al., 2018; Kreyling et al., 2009).

Furthermore, connections of these particles with other unresolved human diseases such as Alzheimer's disease, Parkinson's disease, asthma, bronchitis, and emphysema are also speculated (Zoroddu et al., 2014; De volder et al., 2013). All these pieces of evidence are pointing towards the importance of risks assessment and management procedures for workers in NT industries such as medical and pharma industries, aerospace technology, and chemical and physical products' manufacturers (Voidazan et al., 2018).

It is noteworthy to mention that defining a feasible NMs human health risk management procedure considered as a struggling challenge during the last decade (Warheit, 2018). Thus, the present study focuses on two major aspects of health and

safety risk management and assessment: a- health monitoring, b- audit health in Malaysia. Malaysia planned to become one of the advanced nations in the field of NT by 2020 (Karim et al., 2017). At the heart of this national program, special attention paid to scientific advancements and novel innovations could locate Malaysia in contrast with the rest of the world's scientific and technological progress. A variety of programs formulated since the First National Science and Technology Policy (NSTP) (1986 – 1989), such as the National Policy on Science, Technology, and Innovation (NPSTI); the Industrial Technology Development: A National Action Plan, 1990–2001; the Second national Science and Technology Policy and Plan of Action (NSTP2), 2002–2010; and the National Policy on Science, Technology, and Innovation, 2013–2020.

The NPSTI which grows upon the principal of Science and Technology and Innovation (STI), in its latest version, provides a plan which is going to lead Malaysia towards a dynamic, competitive, and peaceful nation (MOSTI, 2013). Regarding STI, NT in Malaysia considered one of the novel technologies that should be managed under special policy presented by STI (Rahman, 2013). Furthermore, the Malaysian Science and Technology Information Center (MASTIC) (established, 1992), works as a bridge for broadcasting and spreading STI information to a different institution and industrial centers (Official Portal Ministry of Science, Technology, and Innovation (MOSTI). To bring all these different sections into a united practical platform, however, there is a need to develop an extensive policy guideline that addresses the shortcoming and neglected aspects of working with NMs. Looking at the workload ahead, the importance of the health and safety management and assessment issues seems to capture extra attention (Hashim et al., 2009; Abidin et al., 2020).

In Malaysia currently, there are NT laws for NMs workers which makes them eligible to

102 receive legal protection (Ismail et al., 2019). Ismail et al. (2019), however, highlighted that the country began to formulate a proper safety standard regulation for NT. The Department of Occupational Safety and Health (DOSH) presented the 'Guideline on Control and Safe Handling Nano Material' to address some of the principal issues for safe handling of NMs at workplaces, in general terms. According to Ismail et al. (2019), DOSH personnel received no report from NMs capitals, which demonstrate occupational disease and work-related accidents happening for individuals working with NMs. Thus, it remained no choice for them but to express that such records do not exist (Ismail et al., 2019). According to Geraci (2017), to manage the NMs hazards and ventures: '...many precepts of safety and health have to be re-examined.' (Geraci, 2017, p.V).

In Malaysia, to establish risk evaluation procedure for the health and safety of NMs workers, this study explored the following objectives, focusing mainly on health monitoring and auditing:

- 1- To what extent does the health monitoring procedure was carried out for nano-workers in different NT work environments?
- 2- To what extent does the implementation of audit health procedure in NT workplaces considered?
- 3- To what extent current health risk assessment and management concerns for nano- technology workers are known?
- 4- How the NT governing agencies look at the current health and safety assessment procedure of nano-workers?

## Methods

To answer the objectives of this study, the latest NMs safety procedure in both industry and academic NT workplaces in Malaysia investigated via following qualitative approach and research framework.

## Qualitative Approach

This research uses a qualitative approach that helps to understand the circumstances and perceptions of people and the environment. The qualitative approach used as an alternative to the analysis of complex and quantitatively observable phenomena (Geraci, 2017; Suri, 2011; Stuckey, 2013). Data from interviews were analyzed using thematic analysis (Boyatzis, 1998). To conduct the qualitative methodology approach in this research, therefore, interviews have been carefully formulated and carried out in three sectors with a range of approximately 50 to 1000 individuals per case, as well as two academic institutions with more than 1000 students per case. It is necessary to note that the selected academic institutions are today's key players of NT research in Malaysia. In total, 20 individuals from industry and academia took part in the research.

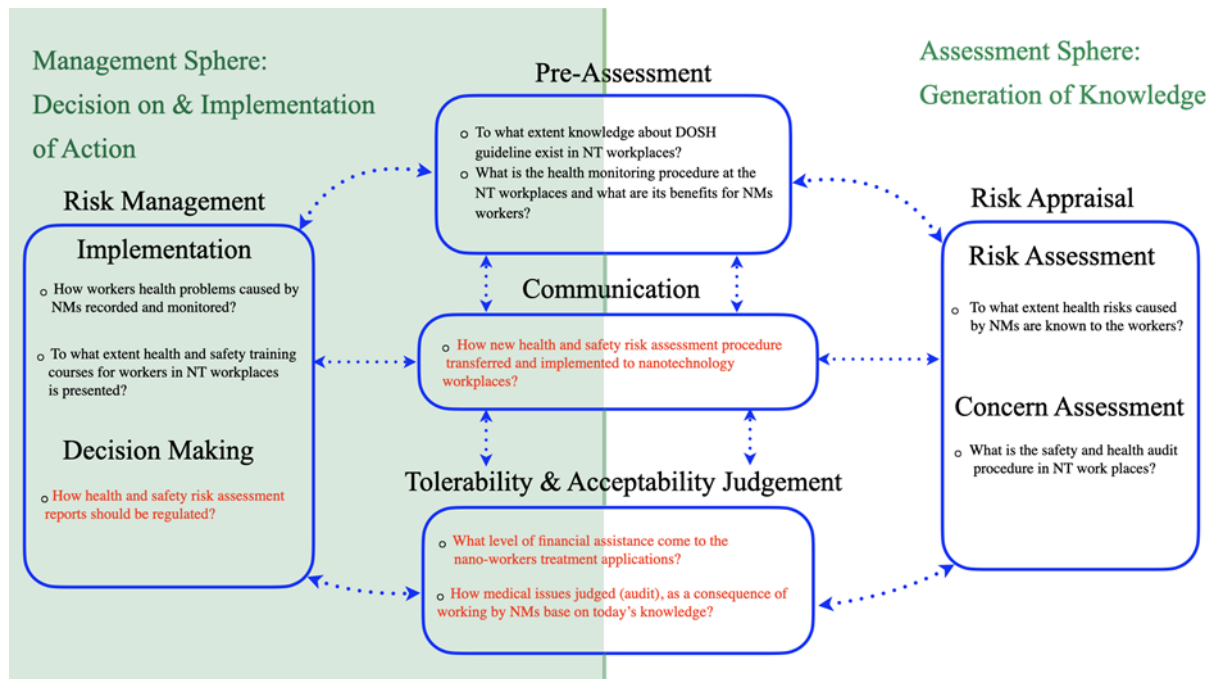
The respondents were selected on the basis of these criteria: position, a period of involvement, and experience working with NMs which include director of the research center, safety director, safety officer, NT experts, manufacture manager, safety manager, and finally workers in both academic and industrial settings. This range of participants designed to obtain the possibility to gather information about the current state of NT safety context in each organization, respectively. The industrial cases were mostly involved with the handling of NMs, which were used in manufacturing filter, hygienic, and cleaning substances. The academic participants, however, were involved with NMs in the research level for various projects aim to develop different aspects of NMs usage.

Each case participates in at least a 60-minute interview. The description and analysis of responses to the questions belong to each objective of this study presented in the research framework (Figure. 1), as well as in the Table 1.

## Research Framework

In general, any new technological advancement requires that the traditional and previous customary regulations to overlooked and reassessed. The Occupational Safety and Health (OSH) organization addresses uncertain risks caused by employing novel technologies at the workplace, via comprehensive legislation presented by the International Risk Governance

Council (IRGC) (Renn, 2009). The present study included two major categories of assessment and management scopes in the IRGC context. The main topics addressed under these scopes are: i) risk appraisal, ii) pre-assessment, iii) communication, iv) tolerability and acceptability judgment, and v) risk management (Fig. 1)



**Figure 1:** A schematic demonstration of the IRGC risk assessment and management framework for Nano-workers used by this study.

In the current research presented questions in semi-structured interviews designed based on these main categories to cover different aspects of occupational risks for nano-workers in relation to the health monitoring and audit health procedures (Figure 1). These questions were evaluated by experts from both academic and industrial

environments, respectively. The NVivo 12 coding process was used for analyzing recorded interviews (Saunders et al. 2015). The presented questions in different parts of the IRGC framework used for interviews to address the main objectives of this study (Table 1).

**Table 1: The extend of the health monitoring procedure for nano-workers in NT environments.** The key questions presented in the interview with a focus on the NMs occupational health monitoring.

<b>Objective 1) To what extent does the health monitoring procedure were carried out for nano-workers in different NT work environments?</b>	
1-	What is <b>the health monitoring procedure</b> at the NT workplaces, and what are its <b>benefits</b> for NMs workers?
2-	How workers <b>health problems</b> caused by NMs recorded and monitored?

**Objective 2) To what extent implementing health and safety audit procedure in NT workplaces considered?**

- What is the **safety and health audit** procedure in NT work places?

**Objective 3) To what extent current health risk assessment and management concerns for NT workers are known?**

- 1- To what extent **health and safety training courses** for workers in NT workplaces is presented?
- 2- To what extent **health risks** caused by NMs are known to the workers?

**Objective 4) How do the NT governing agencies consider the current health and safety assessment procedure of nano-workers?**

- To what extent knowledge about **DOSH guideline** exist in NT workplaces?

**Results**

The findings of this research described in detail under the main objectives of the current research as follow:

**3-1. To what extent does the health monitoring procedure was carried out for nano-workers in different NT work environments?****3-1-1. Health monitoring procedure and its benefits**

The primary purpose of nano-worker health monitoring is to protect them against workplace hazards and to assess the health risk in their working environment. Monitoring workers' health is one critical aspect of the risk control procedure for health and safety. Therefore, to address the current health monitoring procedure for nano-workers in both industrial and academic environments as the first objective of this paper, the interviewees respond to different questions. These questions are presented in the respective sections of the IRGC research framework used in this study (Figure. 1). The findings of this study showed, there was no clear understanding of the health monitoring procedure and detailed knowledge of the advantages of health

surveillance among participating respondents in this research. The academic respondents consider the danger of working with NMs at a relatively low level (Table. 2). Moreover, some of them claimed that working with NMs does not pose any specific risk, first and foremost, requiring health monitoring. The employer was responsible at the academic level for submitting the guidelines on the handling of chemical materials; NMs were, therefore, regarded as other typical chemicals. In addition, the investigations performed at the industry and academic platforms for the safety document revealed that in the existing chemical safety data sheets, there is no clear section on the health monitoring procedure for NMs, also nothing mentioned about their related benefits within the specified Standard Paper (ISO).

*"I did not see anyone monitor my health during the last three years of working in this research lab I work with nanomaterials which are not dangerous and follow safety data sheet (SDS), no one mentioned about a procedure or schedule for a checkup or health monitoring. If there is health monitor in the lab we can protect our*



*health. This is manager responsibility.”*  
(Academic 1)

In addition, comments by nano-workers from industry interviewees did not demonstrate a stronger understanding of the harmful health impact of NMs (Table. 2). The industry respondent stated no details on the health check or health monitoring mechanism. Workers explain that they obtain a range of documents as well as educational material about how to protect the machinery that operates with them in the specified process. There is also an annual safety review and services for these tools, which are very precise. The results of this study did, however, indicate that the safety and health monitoring measures and benefits for employees and the health monitoring process guidance on the workplace were rather inadequate in the industrial areas. Many employees depended on employers' satisfaction with the quality of their jobs and were not clearly supposed to be told about the health monitoring process and associated benefits.

The general conclusion was, therefore, that the employees were interested in the monitoring of their health condition; nevertheless, they had no idea what protocol could be followed and what advantages such a method would have. It is, therefore, important to provide detailed information on health surveillance procedures and their benefits to NMs staff in all of the studied areas. The majority of staff expressed their interest and wish to obtain more information, particularly in academics, on the benefits of health monitoring.

### **3-1-2. Health problem monitoring**

In both groups, the interviewee's statements to this part showed a non-existent policy for health monitoring in the areas under review (Table. 2). Almost all the respondents from academics were in agreement that there are no supports in case someone gets a health issue while working with NMs. However, the location of the chemical substances, in general, is thoroughly checked

to be in the safe and specialized cabinet/chambers. Moreover, it is unclear how the occupational

disease and issues should be measured because there is no records or examinations on the health status of workers before and during work with NMs (Table. 2).

*“When I feel sick at work or if anything harms my health condition during work, I go to hospital or clinic myself... we don't receive any support for treatment from the workplace. The lab manager checks the chemical substances are in the proper cabinets... I think mostly health and safety in this research lab is like concerning about chemical storage and not about researchers.”*

(Academic 2)

An industrial respondent mentioned that their key challenge is to note that they work for the client's satisfaction. The normal practice is, therefore, that the employer plans the work process

entirely concentrated on delivering a product that improves consumer confidence and product reliability. Consequently, health issues for workers come next if they are of any significance. Several of the interviewees mentioned that solving the health problems caused via working with NMs, is their own responsibility. Therefore, they allocate the health monitoring-related budget for themselves, which is a crucial factors that should be taken into consideration. Regardless, to the fact that how much of it is covered by the insurance company, the existing system is not interested in obtaining its share of information about the root of the health issue.

### **3-2. To what extent implementing safety and health audit procedure in NT workplaces considered?**

#### **3-2-1. Safety and health audit**

Interviewees from industries and academics said that their employers does not have any interest in issues related to their health evaluation in their workplaces, (Table. 2). This, however, is regardless of whether or not these complications

are caused by working with NMs. To find out how much the safety and health audit process is implementing in the NT workplaces, workers were asked if they were aware of the presence of any organization that evaluates occurred health problems caused by working with the NMs. This study found in both academic and industry, the safety and health audit procedure is limited to the protection from common chemical substances, such as personal protective equipment. In addition, there is an annual audit safety in the workplaces, which follows the OSH regulation and is related to checking the functionality of safety devices such as fume hood, chemical storage, and fire extinguisher.

*“We have received laboratory safety audit from OSH, such as checking fume hood, fire extinguisher, and chemical storage once a year and safety protection is limited to chemical PPE which is not audit....”*

(Academia 3)

In the industry, respondents also identified that the safety and health audit centered mainly on machinery protection, packaging, and also product delivery but less on the employees safety. NMs workers' health conditions are not specially investigated and inspected. The current situation is that the OSH organization, in the academic and industry sectors, is taking into account the safety chemical standards for NT safety auditing. OSH authorities and professionals rarely audit safety and health situations in both academic and industry. Both groups described safety instructions conducted by OSH and mention that for protection and handling risk in the workplace, standard chemical materials guideline are applied to mitigate risks in the workplace and to protect employees.

### **3-3. To what extent current health risk assessment and management concerns are known to NT workers?**

#### **3-3-1 Safety training course**

Another interesting topic was the review of training courses and programmes for the safe handling of NMs in both academics and factories.

The academic respondents stated that they are certain courses presented by OSH courses for safe handling of usual chemicals and working with them. The findings of this study revealed that these programs and training courses, however, missing some vital criteria, such as a) lack of scheduled follow-up, and monthly or on annual reviewing of the previously presented knowledge, also b) since these programs were not informative-goal-designed, they provide no updated information which clarifies and explains the latest adjustments produced by OSH or any other involved organization. To learn about the newest rules and complementary regulations for safe working with chemicals, the general procedure in academia is to look at the latest SDS provided in the workplace. Another alternative solution is through the online input and update on OSH official website, where all academic NM staff, including those assigned to work with chemicals, have access to the latest materials and knowledge so that they can use it. On the industrial side, however, companies often focused on training employees in such activities that benefited the technological aspect of their jobs. Consequently, these training programmes do not address the occupational hazard of working with the NMs (Table.2). The regular guideline of companies covers only the technical characteristics of their work. The existing training courses, subsequently, are to elevate workers' performance of their job, e.g., equipment manuals, machines systematic services. The exchange of knowledge through the different departments of the organizations often seemed a vital way for nano-workers to interact with their senior managers and supervisors. In most companies, the management board participated in classes to efficiently increase the impact of information flow among employees. Thus, new staff may benefit from previous experiences during this procedure. Interviews with some of the responsible individuals in various factories revealed that this method of communication could increase awareness and knowledge of nano employees and minimize the

potential hazardous behavior that could cause product manufacturing problems and even hurt the production line. The respondents' statements revealed that even the general introduction for safely handling of chemicals is rather primitive.

*"I did not pass any training course for working with NMs, but I have participated in some courses for handling of general chemicals, which were provided and promoted by the company. We follow chemical guidelines, because the point is that NMs are another kind of chemicals."*

(Company 1)

Therefore, in both academic and industry, responses to the question about the health and safety training courses showed these programs are predominantly focused on the safe handling and utilizing chemicals in general, and there was no specified safety education pertinent to working with NMs. Furthermore, a study related to (OSH) safety information and documentation in both academic and industry showed that there is no safety training course available for working with NMs in (OSH) documents. The safety information document for using and handling of materials (OSH) specified for NT workplaces is limited only to general chemical materials. In both environments, the general sense was that chemicals product regulations often engulf the NMs as well; thus, they are treated and managed at the same standard. In this regard, the present study wishes to point out that even safety information about working with chemicals substances require to be reassessed.

### 3-3-2 Health risks comprehension

In academia as well as in industry, comments made by interviewees concerning their relevant knowledge of NMs showed since as previously mentioned, they consider NMs to be like other chemicals substance, therefore, the harmful properties of NMs are not properly recognized. The

analyzed areas provide insufficient information on the possible health risk to human health, either short or long term. (Table. 2). And again, because of the inappropriate understanding of the NMs

nature, nothing more than the usual cautious took into consideration is studied platforms:

*"I do not know much. I know a little bit about the risks. Usually, some chemicals may affect our inhalation, or some can be toxic to our health. Therefore, I use the mask provided in the workplace to protect from those type of chemicals. I think NMs are like other chemicals and for protection can follow chemical safety guideline...."*

(Company 2)

Interviewees' responses indicate that the suggested OSH precautions are inadequate for NT workplaces. There is also a strong need for policy to enact the recommendations. Most employees, including the ones with higher educations, claim that powder-shaped NMs are more hazardous than liquid, and consequently, usage of personal protective equipment can protect them adequately. Also, workers expressed that they believe the shape of the NMs (slurry or powder) has an impact on their related risk level. These results again emphasize on inadequate understanding and knowledge of the danger of nanomaterials in assessed workplaces.

### 3-4. How the NT governing agencies look at the current health and safety assessment procedure of nano-workers?

All different industries, albeit with unequal effects, should be involved in developing a rigorous and systematic health and safety risk management procedure for working with NMs. e.g., DOSH, non-governmental organizations, NT industrial key players, and academic NT research laboratories. Thus, to find the answer for the fourth objective of this paper (presented in Table. 1), questions, debates, and discussions were raised during different interview sessions with the responsible individuals. In answer to the first question underlying this objective, which administrators and managers from both academics and industries questioned, none of these NT workplaces was, unfortunately, able to comply with the DOSH Guideline, mainly resulted by



lack of information about the existence of such instruction. (Table .2).

*“...about DOSH safety guideline for working with NMs I don’t know. I didn’t see this guideline. I know there is chemical guideline which I don’t recall it’s full details at the moment...., Is there a published guideline for handling of NMs?”*

(Academic 4)

In those cases, from both studied areas, in which the responsible board was aware of the DOSH guideline entity, lack of feasible policy for its

implementation is considered as the major gap. The present study, based on the interviews conducted with the national NT center (NNC) and DOSH, found that these organizations are in the process of organizing a series of safety workshops and educational programs for NMs workers in order to increase their awareness of the hazardous NMs. This is a very promising step forward in enhancing workers' understanding of derivatives of working with NMs.

**Table 2.** Related occupational safety and health issues of NMs based on IRGC framework. The following table represent the qualitative data collected from statements after semi-structured interview cases.

Management & Assessment Environment Sphere		Academia	Industry
Pre-Assessment	NMs risk knowledge	Less / Wrong	No / Wrong
Risk Appraisal	NMs Health and safety risk	No	No
	Concern: NMs safety and health audit	No	No
Tolerability & Acceptability Judgement	Crucial for future safety and risk assessment development of NT in Malaysia	<b>Required comprehensive investigation</b>	<b>Required comprehensive investigation</b>
Risk Management	Implementation: Health monitoring, NMs Training program	No	No
	Decision Making: Collecting health reports	No	No

<b>Communication</b>	Transfer information to/from DOSH	<b>Required comprehensive investigation</b>	<b>Required comprehensive investigation</b>
	Industrial safety approach		

## Discussion

At the global level, NT applications started to utilize more than decades before (Sufian et al., 2017; Geraci, 2017; Grieger et al., 2019; Porcari et al., 2019). It is impartial, therefore, to consider the NMs workers as our frontiers in this battlefield, who allow NMs manufacturers to meet international demands and requirements (World Health Organization, 2017). Earlier studies show that the general chemical risk protocol for such workplaces is generally the common policy preferred by companies and research organizations for safe managing NMs. Senior administrators and administrators, on the other hand, are partially responsible for safety and health at work for NMs. Therefore, while a safety climate refers to as a common understanding of safety policies, approaches and application of the standard chemical safety protocol tends to be a weak selection to protect staff from the number of identified risks associated with NMs (Kirkegaard, 2020; Iavicoli, 2019; Dove, 2008). In Malaysia, NT has been part of the Malaysian strategy for new technological growth since 2001. (Karim et al., 2015). The key topics were health risk assessment, including health surveillance, safety and health audit, safety training and risk perception. Employees, specialists and managers from industrial and academic research laboratories were also invited to engage in interviews to address questions according to the key objectives of this research results of responses to the first objective showed that employees have no general knowledge or understanding of the health monitoring benefits, however, the respondents indicated their interest in health inspections and monitoring. Moreover, to date, it agreed that no established health monitoring procedure is available or carried out at any of the workplaces

published in this report. Another question that emerged during this study was whether staff obtained and/or tracked health problems caused by NMs. The findings showed no monitoring of the health of employees in any of the areas analyzed. Medical surveillance is an effective method for tracking health and the risk assessment of NMs. As awareness of medical problems induced by NMs is a growing science, no medical procedure is still recommended for occupational risks of NMs. General medical assessments and health monitoring are therefore a cautious and cautious practice and should be carried out by responsible managers (Nasterlack et al., 2008, Schult et al., 2017). One of the advantages of this technique is to improve the accuracy of the present data set and establish a more reliable health assessment and management protocol for the future (Boutou- Kempf et al., 2011). With regard to the second objective of this research, respondents both from industry and academia indicated that only safety at work is regulated and audited (e.g., fire extinguisher, ventilation system). However, there is no audit health procedure conducted for the nano-workers in these areas. Feitshans (2017) stated previously that audit health and safety notices are parts of the major issues surrounding employer communication on occupational health (Feitshans, 2017). Therefore, in line with the research referred to above Feitshans (2017), the current study also considers that the auditing health needs to be improved beyond policies and that it is necessary to explain each phase by providing more comprehensive and specific rules and also specialist staff in order to enforce the procedure. In response to established health risk assessment and management issues in Malaysia, respondents showed that some of the workplace managers'

courses were designed to educate employees about the harmful effects of chemical products in order to enhance employee occupational risk awareness. These training programmes, however, are not especially linked to the development of employee skills for safe use and management of NMs. In an international study by Iavicoli et al. (2019), companies selected 'general chemical risk management' as the common approach rather than the risk management guidelines defined for NMs (Iavicoli et al., 2019). Kirkegaard et al. (2020) also report on the value of educating workers through training. The occupational safety and health (OSH) organization has already presented a number of guidelines and tools for the management of NMs. However, recent studies have shown that certain NM risk regulations still need to be further established (Greger et al., 2019, Porcari et al., 2019). DOSH has recently released a guideline for the handling and safety use of NMs in Malaysia. However, it should be noted that in nano-workplaces, there is still no established policy to enforce this system. The present study found the general knowledge about the existence of the DOSH guideline was poor in both nano-work environments, industry, and academic workplaces. As a consequence, no clear plan existed to report on the evaluation of health and safety risks. The authors of this research found it surprisingly compelling that statements expressed by both industrial and academic respondents throughout the discourses raised by questions designed in this study, indeed, these factors are the key contributors to the potential growth and promotion of the Malaysian health and safety assessment mechanism for nano-workers.

## Conclusions

The interview response from academics as well as manufacturers in this study is a strong indication of a need for a detailed NT Safety and Health Guideline for Health in Malaysia. The use of the safety culture approach is improved, as laws and regulations are seen as guidelines

that are necessary for enforcing safety and risk management procedures rather than constraints. Through the governing agencies involved in the safety and risk management of the NMs in Malaysia, it will also be possible to enforce this strategy more effectively to identify and establish a more 'protective' policy for nano-workers. It should be noted that the research findings indicate that the DOSH guideline on the safe handling of NMs should resolve the highlighted void and work towards establishing a comprehensive NT safety and health policy. Furthermore, adding a strict health monitoring policy that covers different aspects of health and safety risk management, such as reporting the health monitoring procedure, audit health and communication between involved authorities, is essential to boost the significance of the future policy. In conclusion, this study thus outlined some of the most urgent and perhaps most useful questions for the advancement of NT in Malaysia are to be considered during the earliest phases of future research. *(please, see Fig. 1, highlighted in red).*

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## Conflict of interest

The authors of this study, hereby, express that they have no conflict of interest.

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