of these emissions come from the factories that run agriculture, including fertilizers and pesticides. Time-bound strategies should be developed to phase out polluting agriculture and achieve an agricultural system with a zero-carbon footprint. Further strategies should be developed to sequester carbon emitted by industry through agriculture. The breeding process should strategize on how to sustain farmers' livelihoods through agriculture in the long term. An example of sustainability in the breeding perspective is to have long roots and consider yield based on rainfall data over 100 years. This could be the basic framework for releasing varieties in the context of climate change. While research is at one end of establishing equity and sustainability, other technologies that could drive such change include marketing and economics. Producer companies could effectively determine the movement of the percentage of compensation farmers receive from the consumers' pie of payment.

The role of agricultural researchers must therefore shift from a single objective of increasing yields and incomes to a multi-objective strategy of health, nutrition, climate change, economics, consumers and marketing. This has multiplied the work of scientists and the investment in developing better crop varieties and technologies. Crop breeding gave us solutions to hunger in the early part of the century and has the potential to meet the many challenges we now face. Investment in agricultural research should help to address these multiple challenges. Agricultural research with sustainability objectives across sectors is the need of the hour.

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Nano impacts: from science to society

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Uses of nanotechnology-based products in daily life brings human health under the scrutiny of nanotoxicity and nanosafety domains. Standard guidelines set for nanotoxicity assessment and nanosafety measures are yet to generate public awareness. This gap needs to be bridged by educating society about the toxicity and safety issues of the daily use of nanomaterials. An effort is made here to conceptualize the basic framework for raising awareness about the nanotoxicity and nanosafety of public concerns.

Medical science and technology have made significant progress in the early detection and curing of human diseases. In recent times, many newly emerged biotic factors (BFs) and abiotic factors (AFs) have been detected that cause serious human health issues. Among the most significant BFs, new strains of clinical pathogens of natural mutation origin are worth mentioning. Clinical detection and treatment of human diseases caused by newly emerged pathogens are being made possible, and successes have been made to a great extent. However, the same trend line is not seen with many AFs. Lack of theoretical knowledge, limitations in research modalities and clinical trial guidelines have been found to be the basic possible causes that have delayed dealing with the human health issues originating from AFs. Among the vast arrays of newly emerged AFs, nano-sized (1–100 nm) materials have been found to be hazardous to human and environmental health[1]. It can be recalled that nanoscience and nanotechnology are two important scientific disciplines that have made significant societal contributions. Nanotechnology-based commodities for daily life uses have been manufactured at industrial and global scales, and overall demand is still growing. In this regard, the great contribution in the form of theoretical knowledge made by Richard Feynman is highly appreciated[2]. However, not more than three decades ago, the pros and cons of nanoproducts were included under the global regulation protocols for emerging contaminants, and extensive research has been carried out in the direction of nanotoxicity. The presence of nano-sized AFs, such as nanomaterials (NMs), in the human body and environment has raised serious public concerns. Laboratory investigations carried out *in vitro*, *in vivo* and clinical levels have shown the hazardous nature with sufficient evidence of the genotoxicity and mutation caused by NMs[3]. Significant research progress has been made in the part of nanotoxicity caused by NMs. However, due to the complex physicochemical properties and lack of standard analytical techniques, many aspects of the nanotoxicity that can be triggered by NMs are yet to be uncovered. From a societal point of view, it is pertinent to have general

Table 1. Possible routes of entry of nanomaterials into human body and safety measures for handling nanomaterials

Routes of exposure of nanomaterials into human body	Safety measures
Dermal	Wearing of gloves and full sleeve dress
Ingestion	Food items should be kept away from the contamination of nanomaterials
Inhalation	Nanomaterials are to be handled in a form of a solution or on a substrate so that they are not easily air-transported. Use of respiratory air filters N100 or N95 is highly recommended
Open wounds	Nanomaterials should not be handled with open wounds as entry of nanomaterials can take place easily through such wounds
Ocular	Wearing of safety glasses and goggles and not wearing of contact lenses are highly recommended while handling nanomaterials

safety guidelines for NMs so that the public can be made aware of the possible toxicity caused by these AFs. How these nano entities can affect human health through the food chain and environmental routes should be discussed and published in a public forum. Researchers have a significant role to play before such guidelines are made available for public access. A piece of information on the generalized view covering the simplified details of the negative impacts of NMs on human and environmental healths can be foreseen as the need of the hour. Moreover, based on the recent trends of scientific findings on the possible health hazards that can be caused by NMs should be discussed in terms of practical grounds of human activities such as the uses of nanoproducts and exposure to NMs, among others.

The presence of natural nano-sized particles in the environment (air, water and earth) was not well explored until it was found that sources of NMs can also be of anthropogenic origin. Since the inception of the concept of nanotoxicity, a global evolution of experimental-based knowledge has occurred in the last two decades. One of the major conclusions made from the research findings is that irrespective of the origin (natural or anthropogenic) of NMs; the toxicity is primarily controlled by composition, size, shape, surface properties and dose (time × concentration) of NMs[4,5]. These findings have helped develop nanotherapeutics for addressing challenging issues of human health. However, assessing nanomaterial safety aspects of human health is not yet understood in greater detail. Apart from biomedical applications, NMs have been added as one of the ingredients in many cosmetic and hygiene products, food items and fertilizers. The basic issue in nanotoxicity is coming in direct contact with NMs and dose-dependent effects on human health. Although routes of exposure into the human body and possible negative impacts of NMs have been well identified, progress made in translational aspects (dissemination and implementation) and raising awareness about nanotoxicity in the public domain is below par. Educating society on a particular subject matter requires organizing a general awareness programme by the authorized organization and mandatory inclusion of this new discipline of science in the course curriculum at least at the high school level. Education systems in many countries have developed nanoscience courses starting at the graduation level. However, such courses are mostly oriented towards theoretical and application domains, and making such contents generalized for public awareness programmes is not possible.

Before handling NMs, it is important to have adequate knowledge about the possible exposure routes of NMs into the human body. Basically, NMs can enter the human body through dermal, ingestion, inhalation, open wounds and Ocular. For each exposure route, recommended safety measures are presented in Table 1.

Nanosafety issues have been made public for nanoproducts such as food items and fertilizers[6]. However, the documented information needs to be interpreted to the end users in a simplified way and preferably in local languages. Nanosafety guidelines followed in laboratory/industry might not fit the practical requirement of end users, and in that case, making the necessary modification to the existing guidelines should be considered by the authorized agencies/institute/person. Nanotoxicity is a newly emerged subject, and raising awareness in the public domain will require the engagement of well-trained and skilled professionals who can deliver the scientific contents of nanosafety guidelines or nanotoxicity subject in layman's term.

With the growing demand for nanotechnology-based products for human application, it is high time to make the public aware of the negative impacts of nanoproducts and available personal protective equipments for safety measures. Course modules, documentaries, magazines and workshops are some of the strong tools that might help in educating society about nano impacts. It is expected that the contents of the present paper will help initiate such approaches to educate society on the same.

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