



Industrial Training/Internship in Toxicology: A Bridge Between Toxicology Awareness in Academics and Industries

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Abstract

Toxicology has been in rapid demand for the past couple of years. Due to the recent advancements in technology, Toxicology studies are experiencing a major paradigm shift in terms of research and awareness. However, academics lag in exploring this field as a major subject in teaching. This review paper describes a) how an internship in toxicology helps in making up the gap between academics and industries. b) how an internship in this crucial field drives students to explore it as a career option. c) highlights the fact that toxicology is not a singular aspect in terms of research but is multidisciplinary and is voluminous and wide when it comes to toxicity studies. d) how an internship is rewarding in terms of professional and generic skill development for students. e) highlights the gap between the academic curriculum in terms of toxicology and the research aspect of toxicology in industries. This review sheds a light on how India has been keeping up with the pace by offering multiple courses in toxicology and a vast number of contract research organisations performing toxicology studies. This review paper will create awareness about this notable field among students and encourage them to the internship.

Keywords: Academic Institutes; Curriculum; Internship; CRO and Industries; Toxicology; Student

Introduction

Certain areas of industrial research remain unexplored when it comes to the correlation between the subjects of academics and the correspondent area of industrial training. There are several industries related to healthcare and hospital management, diagnostics, medical technology, biomedical fields, pharmaceutical industries, etc. that have a firm foot in the field of science. Due to their dominance, students are attracted to navigate their prospects in the same hence overshadowing some fields that are of utter importance such as phylogeny, ecology, evolutionary psychology etc. These fields of science are slowly propelling forward in terms of exploration but are still highly underrated as they are not given much stature due to their negligible consideration in academics. Also, the in-field practical knowledge concerning relevant

industries and the application of the accumulated theoretical knowledge in actual fieldwork is overlooked during the academic curriculum. All the above-mentioned aspects are also applicable to toxicological science. Currently, there are several industries providing services for the assessment of the safety of chemicals introduced to humans. These include preclinical studies, risk assessment, and regulatory submission. Today, toxicologists are in high demand because not only do they have the merit of basic sciences such as chemistry, biology, medicine, or mathematics, they are adept at delivering an integrated view [1]. Toxicology is the only domain that performs risk assessment and analysis of all the major healthcare industries cumulates cosmetics, industrial chemicals, food and food additives, biological products, veterinary products, vaccines, pharmaceutical products, medical devices, and agrochemical products.

At present, mega chemical and pharmaceutical industries want higher institutions, to first tutor toxicologists about the functioning and flow of the field and second, conduct research in collaboration with a scientist from the industry that will in turn embolden the expansion of this science [1]. For those who are aspiring to cut back on an experiment performed on animals, novel approaches for safety assessments are mandatory, with the ultimate foresight of developing methods that allow safety assessments without animal testing [2,3].

During risk evaluation, toxicologists need to measure results and take into account various methodologies, along with the experimental skills and subjects taught at these institutions. Toxicology is a multidisciplinary, data-rich field of science that has access to avant-garde technologies to scrutinize mechanisms causative of adverse ramifications on exposure to xenobiotic chemicals, especially related to human health. Toxicology is further divided into a wet lab and a dry lab. The wet labs are used for testing and analysing biological test substances while dry labs majorly focus on computational analysis and modelling using mathematical aspects and on computers. However, the science of safety doesn't confine to a particular field. Rather, the size of themes it encompasses should be viewed as a new horizon ready to evolve with time [4].

Thus, higher institutions need qualified academic professionals and well-equipped laboratories for research and training [1]. Higher educational institutions must take the first step by linking themselves to research related connections in the industry including scientists and research officers. This will steer students to explore the field in-depth and censoriously equip them with sufficient ideas about it. To bridge the gap of knowledge in the field of toxicology, academic research, or an internship/training in the same can be viewed as a starting point towards the elucidation of this problem.

Students are well versed with theories and methodologies taught during their academic years, but they lack the skill to put those theories to actual use. Traditional practical knowledge taught in higher educational institutes does not suffice. These internships are a source to bridge that gap. They grant a stage to learn and use those theories in the industrial experience. These internships are a simulation of the industrial experience in that students can take

part and gain a greater perspective of the field. This also fosters them to step out of their comfort zone and push beyond their limit to explore other areas to their fullest potential. Education and skill development are not restricted to classroom theories and concepts. Practical exposure to the labour market equips students with professional workflow. These internships are not just about practical exposure. They enhance personal as well as professional skills and teaches them how to strike a balance between these two. Sometimes, these industries that hire interns also give them the opportunity for full-time employment as it is time-saving and cost-effective [5-9] While pursuing such internships students also gain an insight into the career choices and their inclination towards it.

The vital benefit of such industrial training is to gain experience in the real market by obtaining practical knowledge from industrial training [10-14] and potential career exploration that help students to choose which career is best suitable for them. Along with this, networking for the development of contacts and major acquaintances for future references [5,15], feedback from professionals and supervisors for progress and understanding [16-18], resume building, and polishing that gives an upper hand in competition [19] are a part of innate benefits of an internship. In addition to this, the university benefits in terms of students' satisfaction with the facilities and the aid they provide, including paid/unpaid internships and employment for students which, encourages the institution's popularity for the services it gives [20]. The major gain is professional skill development that includes problem-solving, teamwork, adaptability, and flexibility, decision making, critical and rational thinking, time management skills, efficient communication skills, understanding the mission/vision of the organisation and aligning the goals accordingly, leadership skills, keep harmony among the team members, and being an active listener.

Hypothesis and data

Toxicology helps in the evaluation of hazards that might stem from using chemicals, pesticides, biocides, food and cosmetics on humans, the environment, and animals [5,21]. All safety measurements arise from these toxicology studies and scientific investigations of substances embedded with toxic properties.

Toxicology is a conglomerate of various fields and hence is multidisciplinary. Being considered the science of safety, it has a

diverse array of branches to offer but the four principal disciplines are Environmental, Economic, Pre-Clinical and Forensic Toxicology. Environmental Toxicology deals with the study of the effects of toxic substances occurring in natural and synthetic environments that includes details of the assessment of toxicity, metabolism of toxic substances by animals and plants, details of toxic substances released into the environment by microorganisms and a study of pesticides and herbicides [22]. Economic Toxicology deals with the potentially harmful effects of chemicals that are intentionally administered to living organisms to achieve a specific beneficial effect [23]. Forensic toxicology is the science of applying the principles of analytical chemistry and toxicology for medico-legal purposes where the results are likely to be used in court or for administrative actions. Forensic toxicology disciplines cover death investigation, and aspects related to behavioural or human performance such as impaired driving due to drug consumption, steroid use by athletes, and workplace drug testing [24]. Pre-clinical toxicology deals with determining the safe dose that supports clinical trials performed on humans and characterises the safety profile of test substances. These studies can be performed in-vivo and in-vitro. Pre-clinical studies investigate the potential undesirable pharmacodynamic effects of the test substance. The major branch being pre-clinical toxicology is further divided into short-term and long-term repeated-dose toxicology, reproductive toxicology, ecotoxicology, carcinogenicity, and mutagenicity.

As compared to India, the subject is quite popular in Europe and North American nations where the societies of toxicology have been functional since the late 60s and 70s [25]. India has slowly gained momentum in toxicology studies and curricula. Many Indian universities offer toxicology as an elective, major subject, or a specialisation in combination with other subjects. But the problem arises when students are not well acquainted with this field and its significance in the research. A field such as this needs a detailed outline at a nascent stage such as the last year of graduation in the form of a subject and not just a topic. Delineation of the content of an optimal core curriculum, both pre-doctoral and post-doctoral by professionals representing many applications of toxicology could be a primary step in developing such a training program. The availability of faculty and laboratory facilities to qualified institutions could also be a successful cooperative endeavour. A training program can probably encourage internships whereby

students learn how to work at the bench well enough to convey to other trainees what they have learned, once they are on their own [26].

Many universities in India have begun to include toxicology as a specialisation subject, as an elective subject or as an added subject with specialisation. Indian Universities have taken a step forward in toxicology curriculum by offering different specialisation courses. Some of them are:

- The renowned Jamia Hamdard University in Delhi has a special department dedicated to elementology and toxicology that offers a post-graduation degree in the same [27].
- National forensic sciences University in Gandhinagar, Gujarat has a separate school of medico-legal studies that is only dedicated to toxicology studies namely, MSc in toxicology and PG diploma in Forensic Toxicology (<https://www.nfsu.ac.in/m-sc-toxicology>, <https://www.nfsu.ac.in/pg-diploma-in-forensic-toxicology>)
- Department of Zoology, a specialised faculty and department in the Maharaja Sayajirao University of Baroda dedicated to zoology offers toxicology as an elective subject for post-graduation students (The Maharaja Sayajirao U[https://www.msubaroda.ac.in/academics/FOS/department/ZOO/Programs/125niversity of Baroda \(msubaroda.ac.in\)](https://www.msubaroda.ac.in/academics/FOS/department/ZOO/Programs/125niversity%20of%20Baroda))
- Agartala Government Medical College, Agartala, Tripura has para-clinical studies which offer a special department of Forensic Medicine and Toxicology that offers MD in the said course (<https://agmc.nic.in/>)
- Bombay College of Pharmacy offers a master's in pharmacology and toxicology (integrated) (https://bcp.edu.in/Faculty_of_Pharmacology_and_Toxicology.aspx#section2)
- The University of Madras has a special department of pharmacology and environmental toxicology that includes an MSc in toxicology, an MPhil in environmental toxicology (inter-disciplinary) and a PhD in environmental toxicology (<https://www.unom.ac.in/index.php?route=department/department/deptpage&deptid=55>)

- The National Institute of Ayurveda offers a unique department named the Department of Agad Tantra (Medical Jurisprudence and toxicology) [27]
- SCMS Kochi offers MSc in Toxicology (<https://targetstudy.com/institute/1607/school-of-communication-and-management-studies/>) [28]
- Annamalai University: MSc Zoology offers Toxicology as an elective subject (https://www.annamalaiuniversity.ac.in/studport/download/Handbook/2019/Science/msc_fiveyear_2019-20.pdf, https://www.annamalaiuniversity.ac.in/studport/download/Handbook/2019/Science/msc_twoyear_2019-20.pdf) [29]
- Chaudhary Charan Singh University, Meerut, UP a renowned university has a department of toxicology that offers an MSc in Toxicology as well as a PhD in toxicology (<https://ccsuniversity.ac.in/ccsu/index.php>) [30]
- Dr Indravadan P Patel institute of medical Technology and research offers an MSc in Toxicology and a PG diploma in toxicology (https://www.drippmedical.in/index.php?mo=edu_dtl&coucod=4, https://www.drippmedical.in/index.php?mo=edu_dtl&coucod=9) [31]
- ToxIndia contract research organisation - Pune, Maharashtra [36]
- Syngene, a contract research organisation- Bangalore, Karnataka (<https://www.syngeneintl.com/solutions/discovery-safety-assessment/>) [37]
- Anthem Biosciences, a Contract Research and Innovation Service Provider (CRISP) – Bangalore, Karnataka [38]
- Institute for Industrial Research and Toxicology, Delhi (<https://www.iirt.in/services.htm>) [39]
- Liveon Biolabs, contract research organisation, Karnataka [40]
- Lavender toxicology research private limited (LTRPL), contract research organisation- Ghaziabad, Delhi NCR (<https://lavenderresearch.co.in/services/>) [41]
- JDM Research, contract research facility-Vadodara, Gujarat (<https://www.jdmresearch.com/services/regulatory/>) [42]
- Dabur research foundation (DRF)-Ghaziabad, Uttar Pradesh (<https://www.daburresearch.in/drug-discovery-development.html>) [43]
- Eurofins Advinus, contract research foundation- Bangalore, Karnataka (<https://www.advinus.com/services/biologics-testing-services/>) [44]
- Averin Biotech Laboratories-contract research organisation- Hyderabad, Telangana [45]
- Bioscience Research Foundation-contract research organisation-Chennai, Tamil Nadu [46]
- Orchid Pharma - Chennai, Tamil Nadu [47]
- Torrent Pharmaceuticals- Ahmedabad, Gujarat
- Zydus Research Center and Pharmaceutical Industry - Ahmedabad, Gujarat
- Dr Reddy's Laboratories Limited-Hyderabad, Telangana
- Sun Pharmaceutical Industries Ltd. (Sun Pharma) – Vadodara, Gujarat

As mentioned above, the universities in India are offering several courses in toxicology but just for the masters and further studies. Students are not well versed with this science and line of research. To link this, an internship in the same line helps them to receive some brief idea about toxicology as a subject in clinical trials and not just a singular topic in a major subject of the curriculum. Today, India is appearing as one of the top runners in the field of toxicology in terms of several pharmaceutical and agrochemical industries and CROs (Contract Research Organisations). A few of them are mentioned below:

- Indian Institute of Toxicology - Pune, Maharashtra (<https://iitoxicology.com/studytypes.htm>) [32]
- APT Testing and Research Pvt. Ltd. (formerly known as National Toxicology Centre) -Pune, Maharashtra (<https://ntc-apt.com/services/>) [33]
- JRF Global, a contract research organisation- Valvada, Gujarat (<https://www.jrfglobal.com/services/pharmaceutical-services.aspx>) [34]
- CSIR-Indian Institute of Toxicology Research – Lucknow, Uttar Pradesh [35]

If students earn a chance to pursue a training/internship in such industries and CROs, not only it will open a new career prospect for them, but it will also highlight the importance of this crucial field. It will allow them to collaborate with researchers and scientists and understand the concepts.

An internship in the field of toxicology will acquaint students with the concept of GLP (Good Laboratory Practices) and various other international standards such as OECD (Organisation for Economic Co-operation and Development), US FDA (United States Food and Drug Administration) and ISO (International Organisation for Standardization) that are the foundation of such research foundations and pharmaceutical industries. It also helps to understand the regulatory requirement of different countries related to their subject. They give an account of how such practices and international standards are implemented and how they serve the purpose of running an organisation ethically and systematically. GLP means a quality system related to the organisational process and the conditions under which non-clinical health and environmental safety studies are planned, performed, monitored, recorded, archived, and reported [48]. GMP is the part of Quality Assurance that ensures that products are consistently produced and controlled to the quality standard appropriate to their intended use and as required by the marketing authorisation [49].

Such internships also familiarise students with how industries cope with regular advancements in the fields and obtain the highest level of technology which are generally not observed in academic institutions. Facilities and equipment that are gigantic in size and capable of bulk orders can only be found in industries. Research organisations and industries can afford specialised professionals for each step. These professionals have mastered that skill set which enhances efficiency. Also, the level of documentation done in industry and organisation is a notch up than in academic institutes as the data management is done meticulously in an organized manner to enhance workflow.

Discussion

Internships have many underlying advantages when done with vigour and enthusiasm. The advantages of internships/industrial training are not just finite to professional skill development, but it also enhances generic skill development. Generic skills such as learning how to prioritise work-related tasks in order of importance, urgency etc., understanding one’s strengths and weaknesses and working on them, and firsthand knowledge of the field by interacting with colleagues. Owing to this, students/

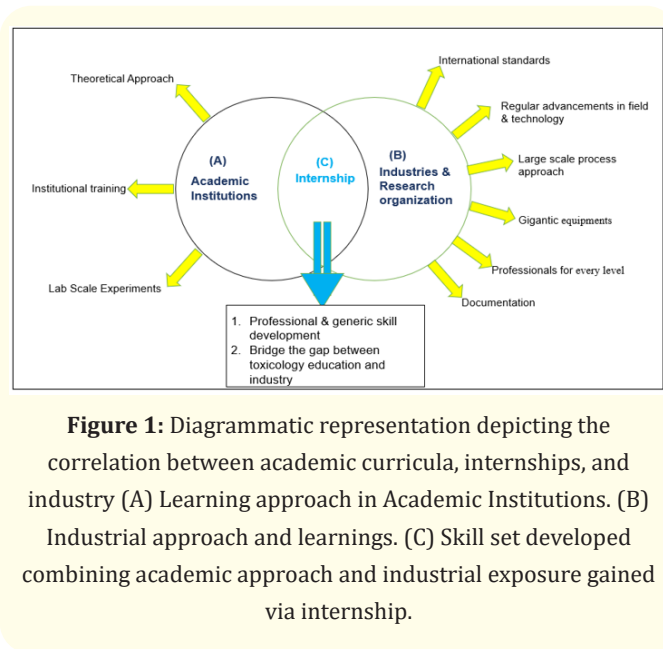


Figure 1: Diagrammatic representation depicting the correlation between academic curricula, internships, and industry (A) Learning approach in Academic Institutions. (B) Industrial approach and learnings. (C) Skill set developed combining academic approach and industrial exposure gained via internship.

interns have an edge in the market. Also, growing accustomed to workspace culture helps students understand a systematic workflow and hierarchy. It teaches interns how an organisation thrives under pressure. Sharpening observational skills (act like a sponge and absorb everything) and disintegrating the dilemma about a particular subdivision of a subject or field that has been preconceived while pursuing graduation, widening the horizon.

Such internships highlight the importance of many fields that are prominent in the industry but not in academics. Academic institutions give a brief outline of Toxicology as a part of the curriculum whether as an elective or as a major. But such vital fields require a comprehensive introduction at the graduation level. The present data above represents the fact that the number of educational institutes offering toxicology curriculums is fewer than the Research organisation and industries performing toxicology studies in India. However, the prevalence of toxicology has recently come to light swiftly. In India, higher authorities, scientists, and government officials have helped in unfurling its importance by spreading awareness about the field by providing specific training courses in toxicology for example CSIR (Council of Scientific and Industrial Research, India) and NGCMA (National GLP Compliance Monitoring Authority, India).

Hence, students should be encouraged to take up internships in these organisations to overcome the gap. Advocating for the value of toxicology in sustaining a safe and healthy world will greatly increase support for toxicology education and training [50]. This will also acquaint students with concepts of good manufacturing practices, good laboratory practices and other such international standards implemented in the organisation. Looking at recent trends, a lot of efforts have been made in establishing the concept of 'preventive toxicology'. Owing to this, latent risks and hazards have been recognized using novel and sensitive methods such as *in silico* toxicology (computational toxicology); (b) *in vitro* methods complementing and replacing animal testing; (c) 'omics' approaches including transcriptomics, proteomics, metabolomics, and 'epigenomics'; and (d) physiologically based toxicokinetic modelling [5]. These concepts should proliferate in a way that new technologies and safety assessments coalesce into one. With such advances in industries, students can build a foundation of toxicology concepts at a nascent level that is not found in academics.

Conclusion

As mentioned above, Toxicology lags in terms of academia and requires to be considered a vital subject in terms of research. To overcome this concern, an internship in the same field should be provided. Working up close with researchers in toxicology will not only encourage students to consider it as a career option but will also equip students with toxicology knowledge, commencing from the identification of hazards to assessing the risk by identifying the safe dosage for human beings. Industries should allow students to explore this field in depth and hence scout for potential future employment. Academics should weigh up toxicology in their course curriculum for it has a pronounced influence on students to contemplate it as a career option.

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Conflict of Interest

There has been no conflict of interest found.

Bibliography

1. Gundert-Remy Ursula, *et al.* "Toxicology: a discipline in need of academic anchoring—the point of view of the German Society of Toxicology". *Archives of Toxicology* 89 (2015): 1881-1893.
2. Jennings Paul, *et al.* "SEURAT-1 liver gold reference compounds: a mechanism-based review". *Archives of Toxicology* 88 (2014): 2099-2133.
3. Adler Sarah, *et al.* "Alternative (non-animal) methods for cosmetics testing: current status and future prospects—2010". *Archives of Toxicology* 85 (2011): 367-485.
4. Collins Francis S, *et al.* "Transforming environmental health protection". *Science* 319.5865 (2008): 906-907.
5. Gault Jack, *et al.* "Undergraduate business internships and career success: are they related?". *Journal of Marketing Education* 22.1 (2000): 45-53.
6. Beard Deborah F. "The status of internships/cooperative education experiences in accounting education". *Journal of Accounting Education* 16.3-4 (1998): 507-516.
7. Beckett Helen. "All good practice". *People Management* 12.5 (2006): 38-40.
8. Callanan Gerard and Cynthia Benzing. "Assessing the role of internships in the career-oriented employment of graduating college students". *Education+training* (2004).
9. Mello Jeffrey A. "Enhancing the international business curriculum through partnership with the united states department of commerce: The "E" award internship program". *Journal of Management Education* 30.5 (2006): 690-699.
10. Farrell Ann M. "What Teachers Can Learn from Industry Internships". *Educational Leadership* 49.6 (1992): 38-39.
11. Fosdick James A. "Post-interns change views of the media, J-Education". *The Journalism Educator* 34.2 (1979): 22-26.
12. Gary LD. "My summer intern experience at First Union Capital Markets Group". (1999).
13. Gault Jack, *et al.* "Effects of business internships on job marketability: the employers' perspective". *Education+Training* 52.1 (2010): 76-88.

14. Raskin Miriam S. "The Delphi study in field instruction revisited: Expert consensus on issues and research priorities". *Journal of Social Work Education* 30.1 (1994): 75-89.
15. Schambach Thomas P and Jim Dirks. "Student Perceptions of Internship Experiences". (2002).
16. Brooks Linda, *et al.* "The relation of career-related work or internship experiences to the career development of college seniors". *Journal of Vocational Behavior* 46.3 (1995): 332-349.
17. Johari Abbas and Amy C Bradshaw. "Project-based learning in an internship program: A qualitative study of related roles and their motivational attributes". *Educational Technology Research and Development* 56 (2008): 329-359.
18. Narayanan Vadake K., *et al.* "Determinants of internship effectiveness: An exploratory model". *Academy of Management Learning and Education* 9.1 (2010): 61-80.
19. Veenendall Thomas L and Andrew R Freeman. "Making an Internship Program Successful: The Necessary Ingredients". (1983).
20. Barry Hocking J., *et al.* "A knowledge transfer perspective of strategic assignment purposes and their path-dependent outcomes". *The International Journal of Human Resource Management* 15.3 (2004): 565-586.
21. Lilienblum W., *et al.* "Alternative methods to safety studies in experimental animals: role in the risk assessment of chemicals under the new European Chemicals Legislation (REACH)". *Archives of Toxicology* 82 (2008): 211-236.
22. Duffus John H. "Environmental Toxicology". Edward Arnold (Publishers) Ltd., (1980).
23. Anderson Bruce., *et al.* "Encyclopedia of toxicology". Academic Press, (2005).
24. Wyman John F. "Principles and procedures in forensic toxicology". *Clinics in Laboratory Medicine* 32.3 (2012): 493-507.
25. Jagriti Kumari. "Toxicology: Learning about the impact of chemicals on living beings". *Education Times* October 20, (2020).
26. Rosenblum Marcus. "Manpower needs for toxicology". *Archives of Environmental Health: An International Journal* 16.3 (1968): 438-442.
27. NATIONAL INSTITUTE OF AYURVEDA (nia.nic.in) for as Department of Agad Tantra (Medical Jurisprudence and toxicology).
28. SCMS Institute of Bioscience and Biotechnology Research and Development, Kochi, Kerala | About College | Courses Offered | Contact Details (targetstudy.com) – for MSc in toxicology.
29. msc_fiveyear_2019-20.pdf (annamalaiuniversity.ac.in), msc_twoyear_2019-20.pdf (annamalaiuniversity.ac.in) - MSc in zoology, Annamalai University.
30. Chaudhary Charan Singh University, Meerut (ccsuniversity.ac.in) – Department of Toxicology.
31. Dr. Indravadan P. Patel Institute of Medical Technology and Research:: (drippmedical.in);: Dr. Indravadan P. Patel Institute of Medical Technology and Research:: (drippmedical.in) – MSc and diploma in toxicology.
32. Indian Institute of Toxicology, Pune - INDIA (iitoxicology.com).
33. Services Offered – APT Testing and Research Pvt. Ltd (ntc-apt.com).
34. Pharma/Bio Pharma (jrfglobal.com).
35. Welcome to CSIR – Indian Institute of Toxicology Research, Government of India (iitrindia.org).
36. ToxIndia Contractual Research Organization.
37. Safety Assessment and Toxicology Services | Syngene CRO (syngeneintl.com).
38. Anthembio.
39. Analytical Testing Services in Delhi, Preclinical Services in India (iirt.in).
40. LIVEON BIOLABS.
41. Services – LTRPL (lavenderresearch.co.in).
42. Regulatory (jdmresearch.com).
43. Early Drug Discovery and Development Guidelines in 2022 (daburresearch.in).
44. Biologics | Biosimilars Testing Services | Eurofins Advinus.
45. Biotechnology Services in India | Bio-Services Industry | Biological Projects (averinbiotech.com).

46. Toxicology | BRF (brfchennai.com).
47. OrchidPharma Ltd.
48. Nahler Gerhard and Gerhard Nahler. Dictionary of pharmaceutical medicine. Springer Vienna, (1994).
49. Chaloner-Larsson Gillian., *et al.* "A WHO guide to good manufacturing practice (GMP) requirements. No. WHO/VSQ/97.01". World Health Organization, (1999).
50. Barchowsky Aaron., *et al.* "The Toxicology Education Summit: building the future of toxicology through education". *Toxicological Sciences* 127.2 (2012): 331-338.