Research Article

Insights of Herbal Medicine

Toxicology: It's Basic Instinct & Application In Forensic Field

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Abstract
Toxicology is a scientific discipline, overlapping with biology, chemistry, pharmacology, and medicine that involves the study of the adverse effects of chemical substances on living organisms and the practice of diagnosing and treating exposures to toxins and toxicants. The relationship between dose and its effects on the exposed organism is of high significance in toxicology. Factors that influence chemical toxicity include the dosage, duration of exposure (whether it is acute or chronic), route of exposure, species, age, sex, and environment. Toxicologists are experts on poisons and poisoning. There is a movement for evidence-based toxicology as part of the larger movement towards evidence-based practices. Toxicology is currently contributing to the field of cancer research, since some toxins can be used as drugs for killing tumor cells. One prime example of this is ribosome-inactivating proteins, tested in the treatment of leukemia. Forensic toxicology is the use of toxicology and disciplines such as analytical chemistry, pharmacology and clinical chemistry to aid medical or legal investigation of death, poisoning, and drug use. The primary concern for forensic toxicology is not the legal outcome of the toxicological investigation or the technology utilized, but rather the obtainment and interpretation of results. A toxicological analysis can be done to various kinds of samples. A forensic toxicologist must consider the context of an investigation, in particular any physical symptoms recorded, and any evidence collected at a crime scene that may narrow the search, such as pill bottles, powders, trace residue, and any available chemicals. Provided with this information and samples with which to work, the forensic toxicologist must determine which toxic substances are present, in what concentrations, and the probable effect of those chemicals on the person.

Key words: biology, chemistry, pharmacology, medicine, adverse effects, toxins, toxicants, toxicology, acute, chronic, poisons, aquatic toxicology, ecotoxicology, entomotoxicology, environmental toxicology, exposome, forensic toxicology, in-vitro toxicology, nanotoxicology, occupational toxicology, overdose, pollution, toxicogenomics, toxinology

Introduction

Ancient in practice, toxicology came to be known simplistically as the 'science of poisons,' a poison being any substance that, at a given dose, is capable of causing a harmful outcome when administered, either by accident or by intention, to a living being [1]. Today toxicology can be defined as "the study of all the adverse effects resulting from the interaction of chemicals or physical agents with living organisms." Toxicology is a multidisciplinary science that has grown and expanded by borrowing data from several different areas. It comprises knowledge and methods from basic sciences such as medicine, epidemiology, pharmacy, and even some engineering areas [2]. Toxicological studies include the detection, identification, and quantification of hazards ensuing from human exposure to chemicals (smoke, food, and workplace), public health aspects of toxic agents in the environment (air, water, and soil), and testing of novel pharmaceutical products [3].

Toxicologists are further involved in the development of standards and regulations designed to protect the environment and human health from the deleterious effects of chemical toxicants. With human monitoring studies, toxicology provides important information to both medicine and epidemiology. It contributes to a better understanding of disease etiology, such as that of cancer, and the plausibility of the causal association between disease development and the exposure to hazard agents. Modern toxicology goes beyond the investigation of adverse effects to use toxic agents as tools in molecular biology studies to explore events occurring at molecular and gene cell level. Overall, it encompasses the detection, occurrence, properties, effects, and regulation of toxicants. Not many scientific disciplines are able to achieve the perfect balance between production of science and direct public applications, toxicology may be unique in this regard [4].

History: Dioscorides, a Greek physician in the court of the Roman emperor Nero, made the first attempt to classify plants according to their toxic and therapeutic effect. A work attributed to the 10th century author Ibn Wahshiyya called the Book on Poisons describes various toxic substances and poisonous recipes that can be made using magic. A 14th century Kannada poetic work attributed to the Jain prince Mangarasa, Khagendra Mani Darpana, describes several poisonous plants. Theophrastus Phillipus Auroleus Bombastus von Hohenheim (1493–1541) (also referred to as Paracelsus, from his belief that his studies were above or beyond the work of Celsus – a Roman physician from the first century) is considered "the father" of toxicology. He is credited with the classic toxicology maxim, "Alle Dinge sind Gift und nichts ist ohne Gift; allein die Dosis macht, dass ein Ding kein Gift ist." which translates as, "All things are poisonous and nothing is without poison; only the dose makes a thing not poisonous." This is often condensed to: "The dose makes the poison" or in Latin "Sola dosis facit venenum"[5].

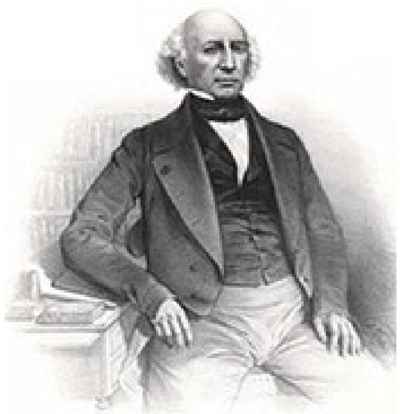

Figure 1: Lithograph of Mathieu Orfila

Mathieu Orfila is also considered the modern father of toxicology, having given the subject its first formal treatment in 1813 in his Traité des poisons, also called Toxicologie générale. In 1850, Jean Stas became the first person to successfully isolate plant poisons from human tissue. This allowed him to identify the use of nicotine as a poison in the Bocarmé murder case, providing the evidence needed to convict the Belgian Count Hippolyte Visart de Bocarmé of killing his brother-in-law [6].

Basic principles

The goal of toxicity assessment is to identify adverse effects of a substance. Adverse effects depend on two main factors: i) routes of exposure (oral, inhalation, or dermal) and ii) dose (duration and concentration of exposure). To explore dose, substances are tested in both acute and chronic models. Generally, different sets of experiments are conducted to determine whether a substance causes cancer and to examine other forms of toxicity.

Factors that influence chemical toxicity:

1. Dosage
2. Both large single exposures (acute) and continuous small exposures (chronic) are studied.
3. Route of exposure
4. Ingestion, inhalation or skin absorption
5. Other factors
6. Species
7. Age
8. Sex
9. Health
10. Environment
11. Individual characteristics

The discipline of evidence-based toxicology strives to transparently, consistently, and objectively assess available scientific evidence in order to answer questions in toxicology, the study of the adverse effects of chemical, physical, or biological agents on living organisms and the environment, including the prevention and amelioration of such effects. Evidence-based toxicology has the potential to address concerns in the toxicological community about the limitations of current approaches to assessing the state of the science. These include concerns related to transparency in decision making, synthesis of different types of evidence, and the assessment of bias and credibility. Evidence-based toxicology has its roots in the larger movement towards evidence-based practices [7].

Testing methods

Toxicity experiments may be conducted in-vivo (using the whole animal) or in-vitro (testing on isolated cells or tissues), or in-silico (in a computer simulation). Non-human animals: The classic experimental tool of toxicology is testing on non-human animals. Example of model organisms are Galleria mellonella, which can replace small mammals, and Zebrafish, which allow for the study of toxicology in a lower order vertebrate in vivo. As of 2014, such animal testing provides information that is not available by other means about how substances function in a living organism. The use of non-human animals for toxicology testing is opposed by some organisations for reasons of animal welfare, and it has been restricted or banned under some circumstances in certain regions, such as the testing of cosmetics in the European Union [8].

Alternative testing methods

While testing in animal models remains as a method of estimating human effects, there are both ethical and technical concerns with animal testing. Since the late 1950s, the field of toxicology has sought to reduce or eliminate animal testing under the rubric of "Three Rs" – reduce the number of experiments with animals to the minimum necessary; refine experiments to cause less suffering, and replace in-vivo experiments with other types, or use more simple forms of life when possible. Computer modeling is an example of alternative testing methods; using computer models of chemicals and proteins, structure-activity relationships can be determined, and chemical structures that are likely to bind to, and interfere with, proteins with essential functions, can be identified.

This work requires expert knowledge in molecular modeling and statistics together with expert judgment in chemistry, biology and toxicology. In 2007 the American NGO National Academy of Sciences published a report called "Toxicity Testing in the 21st Century: A Vision and a Strategy" which opened with a statement: "Change often involves a pivotal event that builds on previous history and opens the door to a new era. Pivotal events in science include the discovery of penicillin, the elucidation of the DNA double helix, and the development of computers. Toxicity testing is approaching such a scientific pivot point. It is poised to take advantage of the revolutions in biology and biotechnology. Advances in toxicogenomics, bioinformatics, systems biology, epigenetics, and computational toxicology could transform toxicity testing from a system based on whole-animal testing to one founded primarily on in-vitro methods that evaluate changes in biologic processes using cells, cell lines, or cellular components, preferably of human origin." As of 2014 that vision was still unrealized [9].

Figure 2: Toxicity testing

The United States Environmental Protection Agency studied 1,065 chemical and drug substances in their ToxCast program (part of the CompTox Chemicals Dashboard) using in-silico modelling and a human pluripotent stem cell-based assay to predict in-vivo developmental intoxicants based on changes in cellular metabolism following chemical exposure. Major findings from the analysis of this ToxCast-STM dataset published in 2020 include: (1) 19% of 1065 chemicals yielded a prediction of developmental toxicity, (2) assay performance reached 79%–82% accuracy with high specificity (> 84%) but modest sensitivity (< 67%) when compared with in-vivo animal models of human prenatal developmental toxicity, (3) sensitivity improved as more stringent weights of evidence requirements were applied to the animal studies, and (4) statistical analysis of the most potent chemical hits on specific biochemical targets in ToxCast revealed positive and negative associations with the STM response, providing insights into the mechanistic underpinnings of the targeted endpoint and its biological domain. In some cases shifts away from animal studies have been mandated by law or regulation; the European Union (EU) prohibited use of animal testing for cosmetics in 2013 [10].

Dose response complexities

Most chemicals display a classic dose response curve – at a low dose (below a threshold), no effect is observed. Some show a phenomenon known as sufficient challenge – a small exposure produces animals that "grow more rapidly, have better general appearance and coat quality, have fewer tumors, and live longer than the control animals". A few chemicals have no well-defined safe level of exposure. These are treated with special care. Some chemicals are subject to bioaccumulation as they are stored in rather than being excreted from the body; these also receive special consideration. Several measures are commonly used to describe toxic dosages according to the degree of effect on an organism or a population, and some are specifically defined by various laws or organizational usage. These include:

LD50 = Median lethal dose, a dose that will kill 50% of an exposed population

NOEL = No-Observed-Effect-Level, the highest dose known to show no effect

NOAEL = No-Observed-Adverse-Effect-Level, the highest dose known to show no adverse effects

PEL = Permissible Exposure Limit, the highest concentration permitted under US OSHA regulations

STEL = Short-Term Exposure Limit, the highest concentration permitted for short periods of time, in general 15–30 minutes

TWA = Time-Weighted Average, the average amount of an agent's concentration over a specified period of time, usually 8 hours

TTC = Threshold of Toxicological Concern have been established for the constituents of tobacco smoke

Types

Medical toxicology is the discipline that requires physician status (MD or DO degree plus specialty education and experience). Clinical toxicology is the discipline that can be practiced not only by physicians but also other health professionals with a master's degree in clinical toxicology: physician extenders (physician assistants, nurse practitioners), nurses, pharmacists, and allied health professionals. Forensic toxicology is the discipline that makes use of toxicology and other disciplines such as analytical chemistry, pharmacology and clinical chemistry to aid medical or legal investigation of death, poisoning, and drug use. The primary concern for forensic toxicology is not the legal outcome of the toxicological investigation or the technology utilized, but rather the obtainment and interpretation of results. Computational toxicology is a discipline that develops mathematical and computer-based models to better understand and predict adverse health effects caused by chemicals, such as environmental pollutants and pharmaceuticals. Within the Toxicology in the 21st Century project, the best predictive models were identified to be Deep Neural Networks, Random Forest, and Support Vector Machines, which can reach the performance of in vitro experiments. Occupational toxicology is the application of toxicology to chemical hazards in the workplace [11].

Toxicology as a profession

A toxicologist is scientist or medical personnel who specializes in the study of symptoms, mechanisms, treatments and detection of venoms and toxins; especially the poisoning of people.

Requirements

To work as a toxicologist one should obtain a degree in toxicology or a related degree like biology, chemistry, pharmacology or biochemistry. Bachelor's degree programs in toxicology cover the chemical makeup of toxins and their effects on biochemistry, physiology and ecology. After introductory life science courses are complete, students typically enroll in labs and apply toxicology principles to research and other studies. Advanced students delve into specific sectors, like the pharmaceutical industry or law enforcement, which apply methods of toxicology in their work. The Society of Toxicology (SOT) recommends that undergraduates in postsecondary schools that do not offer a bachelor's degree in toxicology consider attaining a degree in biology or chemistry. Additionally, the SOT advises aspiring toxicologists to take statistics and mathematics courses, as well as gain laboratory experience through lab courses, student research projects and internships.

Duties

Toxicologists perform many different duties including research in the academic, non-profit and industrial fields, product safety evaluation, consulting, public service and legal regulation. In order to research and assess the effects of chemicals, toxicologists perform carefully designed studies and experiments. These experiments help identify the specific amount of a chemical that may cause harm and potential risks of being near or using products that contain certain chemicals. Research projects may range from assessing the effects of toxic pollutants on the environment to evaluating how the human immune system responds to chemical compounds within pharmaceutical drugs. While the basic duties of toxicologists are to determine the effects of chemicals on organisms and their surroundings, specific job duties may vary based on industry and employment. For example, forensic toxicologists may look for toxic substances in a crime scene, whereas aquatic toxicologists may analyze the toxicity level of water bodies [12].

Compensation

The salary for jobs in toxicology is dependent on several factors, including level of schooling, specialization, experience. The U.S. Bureau of Labor Statistics (BLS) notes that jobs for biological scientists, which generally include toxicologists, were expected to increase by 21% between 2008 and 2018. The BLS notes that this increase could be due to research and development growth in biotechnology, as well as budget increases for basic and medical research in biological science [13].

Toxicology in Forensic Aspects

In the United States, forensic toxicology can be separated into 3 disciplines: Post mortem toxicology, human performance toxicology, and forensic drug testing (FDT). Post mortem toxicology includes the analysis of biological specimens taken from an autopsy to identify the effect of drugs, alcohol, and poisons. A wide range of biological specimens may be analyzed including blood, urine, gastric contents, oral fluids, hair, tissues, and more. The forensic toxicologist works with pathologists, medical examiners, and coroners to help determine the cause and manner of death. In human performance toxicology, a dose-response relationship between a drug(s) present in the body and the effects on the body are examined. This field of forensic toxicology is responsible for building and implementing laws such as driving under the influence of alcohol or drugs.

Lastly, forensic drug testing (FDT) is the detection of drug use among individuals in the workplace, sport doping, drug-related probation, and new job applicant screenings. Determining the substance ingested is often complicated by the body's natural processes (ADME), as it is rare for a chemical to remain in its original form once in the body. For example: heroin is almost immediately metabolised into another substance and further to morphine, making detailed investigation into factors such as injection marks and chemical purity necessary to confirm diagnosis. The substance may also have been diluted by its dispersal through the body; while a pill or other regulated dose of a drug may have grams or milligrams of the active constituent, an individual sample under investigation may only contain micrograms or Nano grams [14].

How certain substances affect your body:

Alcohol: Alcohol enters your central nervous system through the blood stream through the lining within your stomach and your small intestine. Once it is in your blood stream, is passes through your blood brain barrier via blood circulation. The alcohol absorbed will reduce your reflexes, interfere with nerve impulses, prolong muscle responses, and affect other parts of your body as well.

Marijuana: Marijuana, like alcohol, is also absorbed into the blood stream and passed through the blood brain barrier. However, the THC that is released from marijuana attaches to the CB-1 cannabinoid receptors which causes all of the affects that you experience. This include, but not limited to, mood changes, altered perception of time, and increased sensitivity [15].

Cocaine

Cocaine is a stimulant unlike Marijuana or Alcohol. As soon as cocaine enters the bloodstream it reaches the brain in minutes. Dopamine levels are increased intensely and the effects can last up to about 30 minutes. The most common way to use cocaine is by snorting it through the nose but other methods could be by smoking it in a crystal rock form. But because dopamine levels are increased at such a rate this leads to an even worse come down leading to needing a higher dose to get the same effect as the time before if taken again. This is how some addictions begin. Some effects when taken are an increase of energy and happiness, paranoia, rapid heart rate, anxiety, and etc.

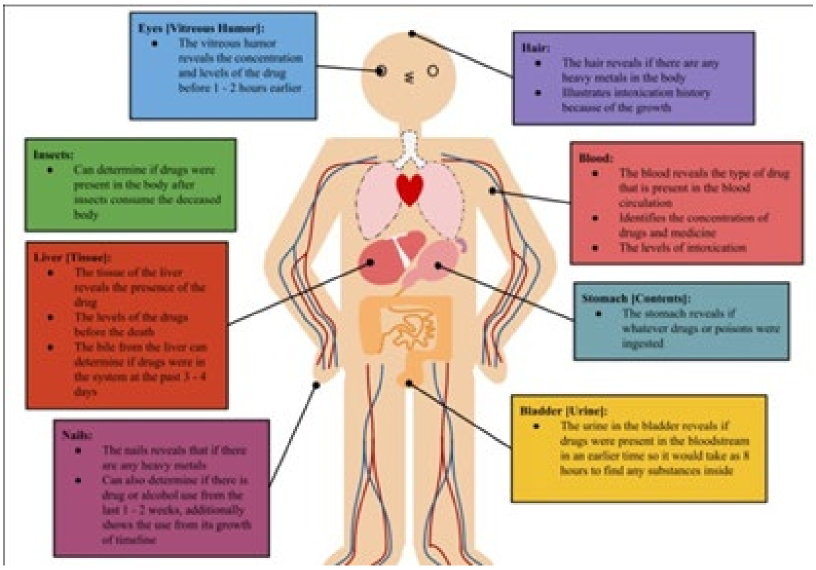

Figure 3: Toxicology channels

Urine

A urine sample of urine that has come from the bladder and can be provided or taken post-mortem. Urine is less likely to be infected with viruses such as HIV or Hepatitis B than blood samples. Many drugs have a higher concentration and can remain for much longer in urine than blood. Collection of urine samples can be taken in a non-invasive way which does not require professionals for collection. Urine is used for qualitative analysis as it cannot give any indication of impairment due to the fact that drug presence in urine only indicates prior exposure. Different drugs can also stay in your urine for different amounts of time. For example, alcohol will stay within your urine for 7–12 hours, cocaine metabolites will stay for 2–4 days, and morphine will stay for 48–74 hours. One drug that will stay in your urine for a varying amount of time (dependent on the usage and frequency) is marijuana. For a single use, it will stay for 3 days, moderate use (4 times per week) will stay for 5–7 days, daily use of the drug will cause it to stay for 10–15 days, and a long-term heavy smoker will have it stay within their urine for less than 30 days [16].

Blood

A blood sample of approximately 10 ml (0.35 imp fl oz; 0.34 US fl oz) is usually sufficient to screen and confirm most common toxic substances. A blood sample provides the toxicologist with a profile of the substance that the subject was influenced by at the time of collection; for this reason, it is the sample of choice for measuring blood alcohol content in drunk driving cases.

Hair: Hair is capable of recording medium to long-term or high dosage substance abuse. Chemicals in the bloodstream may be transferred to the growing hair and stored in the follicle, providing a rough timeline of drug intake events. Head hair grows at rate of approximately 1 to 1.5 cm a month, and so cross sections from different sections of the follicle can give estimates as to when a substance was ingested. Testing for drugs in hair is not standard throughout the population. The darker and coarser the hair the more drug that will be found in the hair. If two people consumed the same amount of drugs, the person with the darker and coarser hair will have more drug in their hair than the lighter haired person when tested. This raises issues of possible racial bias in substance tests with hair samples. Hair samples are analyzed using enzyme-linked immunosorbent assay (ELISA). In ELISA, an antigen must be immobilized to a solid surface and then complexed with an antibody that is linked to an enzyme [17].

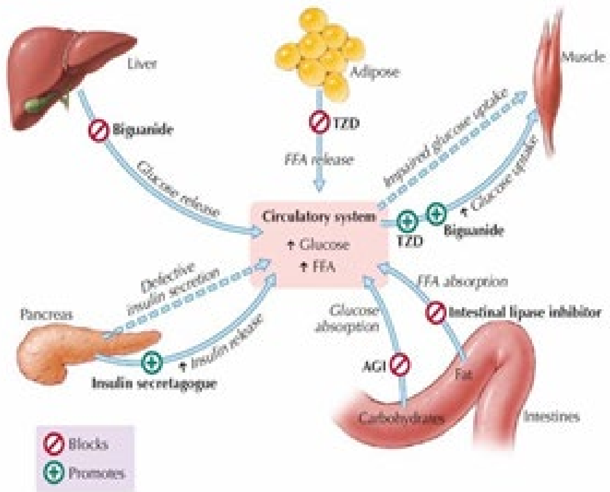

Figure 4: Drugs Target In Body

Bone Marrow

Bone marrow can be used for testing but that depends on the quality and availability of the bones. So far there is no proof that says that certain bones are better than others when it comes to testing. Extracting bone marrow from larger bones is easier than smaller bones. Forensic toxicologists use bone marrow to find what type poisons used. These poisons can include cocaine or ethanol [18].

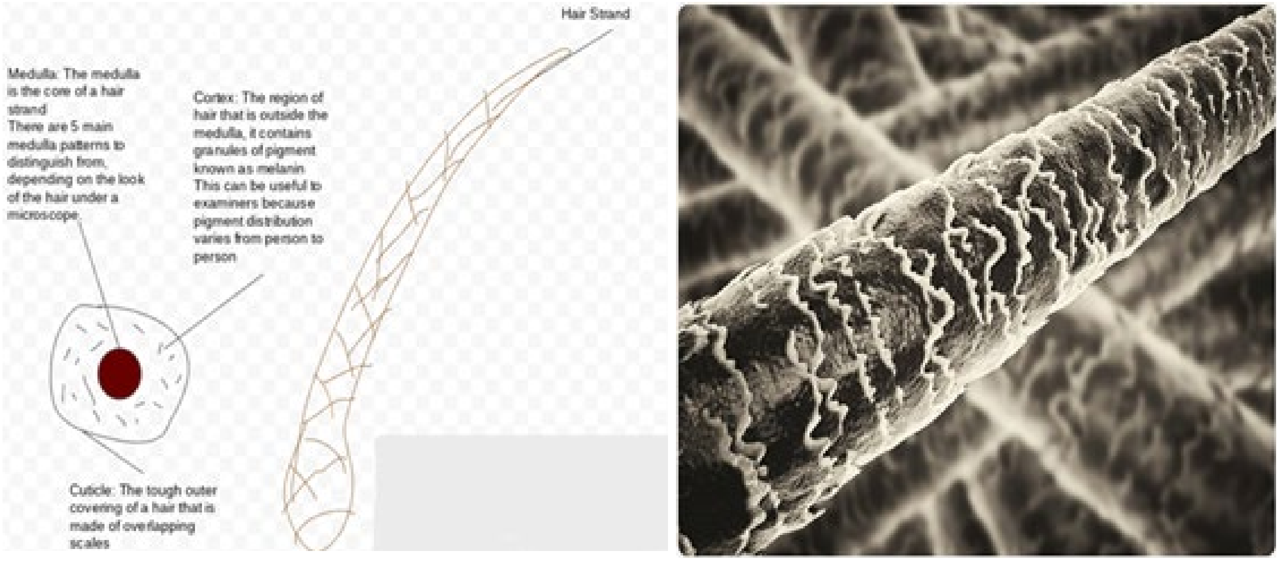

Figure 5: Model how and why a hair strand is useful in Forensic Investigation.

Other

Other bodily fluids and organs may provide samples, particularly samples collected during an autopsy. A common autopsy sample is the gastric contents of the deceased, which can be useful for detecting undigested pills or liquids that were ingested prior to death. In highly decomposed bodies, traditional samples may no longer be available. The vitreous humour from the eye may be used, as the fibrous layer of the eyeball and the eye socket of the skull protects the sample from trauma and adulteration. Other common organs used for toxicology are the brain, liver, and spleen.

Detection and classification

Detection of drugs and pharmaceuticals in biological samples is usually done by an initial screening and then a confirmation of the compound(s), which may include a quantitation of the compound(s). The screening and confirmation are usually, but not necessarily, done with different analytical methods. Every analytical method used in forensic toxicology should be carefully tested by performing a validation of the method to ensure correct and indisputable results at all times. The choice of method for testing is highly dependent on what kind of substance one expects to find and the material on which the testing is performed. Customarily, a classification scheme is utilized that places poisons in categories such as: corrosive agents, gases and volatile agents, metallic poisons, non-volatile organic agents, and miscellaneous.

Immunoassays

Immunoassays requires you to draw blood and use the antibodies to find a reaction with substances such as drugs. The substances must be specific. It is the most common drug screening technique. Using the targeted drug, the test will tell you if it is positive or negative to that drug. There can be 4 results when taking the test. Those results can be a true-positive, a false-negative, a false-positive, and a true-negative [19].

Figure 6: types of toxicity

Gas chromatography-mass spectrometry

Gas chromatography-mass spectrometry (GC-MS) is a widely used analytical technique for the detection of volatile compounds. Ionization techniques most frequently used in forensic toxicology include electron ionization (EI) or chemical ionization (CI), with EI being preferred in forensic analysis due to its detailed mass spectra and its large library of spectra. However, chemical ionization can provide greater sensitivity for certain compounds that have high electron affinity functional groups.

Liquid chromatography-mass spectrometry

Liquid chromatography-mass spectrometry (LC-MS) has the capability to analyze compounds that are polar and less volatile. Derivatization is not required for these analytes as it would be in GC-MS, which simplifies sample preparation. As an alternative to immunoassay screening which generally requires confirmation with another technique, LC-MS offers greater selectivity and sensitivity. This subsequently reduces the possibility of a false negative result that has been recorded in immunoassay drug screening with synthetic cathinones and cannabinoids. A disadvantage of LC-MS on comparison to other analytical techniques such as GC-MS, is the high instrumentation cost. However, recent advances in LC-MS have led to higher resolution and sensitivity which assists in the evaluation of spectra to identify forensic analytes [20].

Detection of metals

The compounds suspected of containing a metal are traditionally analyzed by the destruction of the organic matrix by chemical or thermal oxidation. This leaves the metal to be identified and quantified in the inorganic residue, and it can be detected using such methods as the Reinsch test, emission spectroscopy or X-ray diffraction. Unfortunately, while this identifies the metals present it removes the original compound, and so hinders efforts to determine what may have been ingested. The toxic effects of various metallic compounds can vary considerably.

Conclusion

About 35 years ago, however, T.A. Loomis divided the science of toxicology into three major subdivisions: environmental, economic, and forensic. These subdivisions were in large part based on how humans would come in contact with potentially harmful chemicals. A toxic agent is anything that can produce an adverse biological effect. It may be chemical, physical, or biological in form. For example, toxic agents may be chemical (such as cyanide), physical (such as radiation) and biological (such as snake venom). Toxicity tests are mostly used to examine specific adverse events or specific endpoints such as cancer, cardiotoxicity, and skin/eye irritation. Toxicity testing also helps calculate the No Observed Adverse Effect Level (NOAEL) dose and is helpful for clinical studies.

Paracelsus, Philippus Theophrastus Aureolus Bombastus von Hohenheim, the “father of chemistry and the reformer of materia medica,” the “Luther of Medicine,” the “godfather of modern chemotherapy,” the founder of medicinal chemistry, the founder of modern toxicology, a contemporary of Leonardo da Vinci, Martin Luther. Poisons are classified by such uses as pesticides, household products, pharmaceuticals, organic solvents, drugs of abuse, or industrial chemicals. Toxicology is the scientific study of adverse effects that occur in living organisms due to chemicals. It involves observing and reporting symptoms that arise following exposure to toxic substances. Toxicologists will investigate the mechanisms by which these substances exert toxicity, as well as how to detect the presence of these substances in various sample types. Additionally, toxicology also involves assessing how to effectively treat animals and/or individuals who have been exposed to certain toxicants.

The substances that are assessed by toxicologists includes environmental agents and chemical compounds found in nature, as well as pharmaceutical compounds that are synthesized for medical use by humans. These substances may produce toxic effects in living organisms, of which can include, but are not limited to, disturbances in growth patterns, discomfort, disease and even death. The father of modern toxicology, Paracelsus, historically stated "Only the dose is the poison.' The dose of the substance is an important factor in toxicology, as it has a significant relationship with the effects experienced by the individual. As a result, the dose is the primary means of classifying the toxicity of the chemical, as it reflects the quantity of the chemical that the affected person has been exposed to.

Taken together, any substance has the potential to be toxic if administered under certain conditions and at a given dose. LD50 is a common term used in toxicology, which refers to the dose of a substance that displays toxicity in that it kills 50% of a test population. In scientific research, rats or other surrogates are usually used to determine toxicity and the data are extrapolated to use by humans. A conventional relationship between dose and toxicity has traditionally been accepted, in that greater exposure to a chemical can lead to higher risk of toxicity. However, this concept has been challenged by a study of endocrine disruptors and therefore may not be a straightforward relationship.

There are several branches of toxicology known as subdisciplines or subspecialties, each of which focus on particular aspects of toxicology. These include: [Toxicogenomics, Aquatic toxicology, Chemical toxicology, Clinical toxicology, Ecotoxicology, Environmental toxicology, Forensic toxicology, Medical toxicology, Occupational toxicology, Regulatory toxicology, Chemical toxicology]. Chemical toxicology is a subspecialty of toxicology that focuses on the structure of chemical agents and how it affects their mechanism of action on living organisms. It is a multidisciplinary field that includes computational and synthetic chemistry and also requires the skills of scientists who specialize in the fields of proteomics, metabolomics, drug discovery, drug metabolism, bioinformatics, analytical chemistry, biological chemistry, and molecular epidemiology.

Chemical toxicology relies on technological advances to help understand the chemical components of toxicology more comprehensively. Toxicology and pharmacology are both studies that involve an understanding of chemical properties and their actions on the body; however, these two fields are considerably different in many other aspects. Pharmacology, for example, primarily focuses on the therapeutic effects of pharmaceutical substances and how they can be used most effectively for medical purposes. On the contrary, toxicology more closely studies the adverse effects that canoccur in living organisms that come into contact with chemicals. Toxicologists are also more concerned with measuring the risk of certain substances with risk assessment tools. A toxicologist is someone who has studied toxicology and works with materials and chemicals to determine the toxic effects they may have on the environment and/or living organisms.

References

1. Nandi, K., Sen, D. J., Saha, D., & Saha, A. (2022). Detection of alcohol euphoria in forensic science: European Journal of Pharmaceutical and Medical Research: 9(3), 359-368,
2. Saha, D., Dhabal, S., & Sen, D. J. (2022). Forensic investigation of narcotic drugs through analytical methods: European Journal of Biomedical and Pharmaceutical Sciences: 9(3), 415-423.

3. Saha, D., Dhabal, S., & Sen, D. J. (2022). Forensic science deals with safety armour during warfare explosives: Journal of Forensic Science and Research: 6, 024-041, 2022.
4. Chatterjee, T.M. Sen, D. J. & Mahanti B. (2022). Hair suggests heir of DNA analytical report in forensic science crime scene: European Journal of Biomedical and Pharmaceutical Sciences: 9(2), 325-330.
5. Bakshi, P., Sen, D. J.& Mahanti, B. (2022). Chemical warfare and nerve agents: modern weapon of destruction: World Journal of Pharmaceutical and Life Sciences; 8(2), 133-142.
6. Sarkar, S. Sen, D. J.& Mahanti, B. (2022). Morgue and post-mortem: analysis after death: World Journal of Pharmaceutical and Life Sciences: 8(2), 125-132.
7. Dhabal., S. Nandi., K. Chakraborty., A. Sen, D. J. Bera., K. Biswas., A. Mandal., S. & Saha., D. (2021). CSI (Crime Scene Investigation): first step to unfold the network of crime: Journal of Forensic Science and Legal Medicine: 1(2), 05-16.
8. Nandi. K., Biswas. A., Mandal. A., Sen, D. J., Saha. D., & Mahanti.B. (2021). Neuroscience: The connective boss of human body correlates intel software: European Journal of Pharmaceutical and Medical Research: 8(1), 358-377.
9. Chandra. A. C., Saha. D., Dhabal. S., & Sen. D. J. (2020). Reflection of fluid mechanics on bio-medical engineering; European Journal of Biomedical and Pharmaceutical Sciences: 7(12), 158-171.
10. Vasani. V., Raninga. H., Sen. D. J., & Patel. C. N. (2018). Street drugs as from the height of ecstasy to the depths of hell; as quick as a flash: European Journal of Pharmaceutical and Medical Research: 5(8), 411-426.
11. Patel. V. R., Parmar. J. N., Aal. L. B., Sen. D. J. (2014). Poison gas: as a lethal weapon in chemical warfare: International Journal of Pharmaceutical Research and Bio-Science: 3(4), 332-357.
12. Sen. D. J., Chamanlal. J., Lahiri. S. A. (2011). Three musketeers of genotoxicity: carcinogen, mutagen & teratogen: NSHM Journal of Pharmacy and Healthcare Management: 02, 13-25.
13. Mercatelli, D., Bortolotti, M., & Giorgi, F. M. (2020). Transcriptional network inference and master regulator analysis of the response to ribosome-inactivating proteins in leukemia cells. Toxicology, 441, 152531.
14. Bhat, S., & Udupa, K. (2013). Taxonomical outlines of bio–diversity of Karnataka in a 14th century Kannada toxicology text Khagendra Mani Darpana. Asian Pacific Journal of Tropical Biomedicine, 3(8), 668-672.
15. Wennig, R. (2009). Back to the roots of modern analytical toxicology: Jean Servais Stas and the Bocarmé murder case. Drug testing and analysis, 1(4), 153-155.
16. Hoffmann, S., & Hartung, T. (2006). Toward an evidence-based toxicology. Human & experimental toxicology, 25(9), 497-513.
17. Stephens, M. L., Andersen, M., Becker, R. A., Betts, K., Boekelheide, K., Carney, E., ... & Zurlo, J. (2013). Evidence-based toxicology for the 21st century: opportunities and challenges. ALTEX-Alternatives to animal experimentation, 30(1), 74-103.
18. Mandrioli, D., & Silbergeld, E. K. (2016). Evidence from toxicology: the most essential science for prevention. Environmental health perspectives, 124(1), 6-11.
19. Schreider, J., Barrow, C., Birchfield, N., Dearfield, K., Devlin, D., Henry, S., ... & Embry, M. R. (2010). Enhancing the credibility of decisions based on scientific conclusions: transparency is imperative. Toxicological Sciences, 116(1), 5-7.
20. Adami, H. O., Berry, S. C. L., Breckenridge, C. B., Smith, L. L., Swenberg, J. A., Trichopoulos, D., ... & Pastoor, T. P. (2011). Toxicology and epidemiology: improving the science with a framework for combining toxicological and epidemiological evidence to establish causal inference. Toxicological sciences, 122(2), 223-234.