Applied Chemical Engineering in Crime Laboratory

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Abstract

The career of Chemical Engineering presents among the areas studied several analytical techniques in common within the laboratory field with the field of Criminalistics, these techniques are used for the detection of foreign components within samples of biological and non-biological origin that alter the behavior of an individual or end with the death of the same, the results are analyzed by comparison with established patterns that allow to give a reliable interpretation to be presented to a judge. The objective of this study is to collect information to determine the areas within the criminalistic and forensic field where a chemical engineer can be of support, taking advantage of his knowledge in the different analytical techniques and helping in the interpretation of the results of these, thus allowing to contribute to the legal procedures that are carried out in the cases presented before the law.

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INTRODUCTION

In order to examine the research topic, the concepts that comprise the two branches to be studied must be clear. Therefore, an analysis of the processes carried out both in chemical engineering and in criminalistics was carried out, in order to later determine the methods and techniques in common.

Engineering according to the definition of the Royal Academy of the Spanish Language (RAE) "is a set of knowledge oriented to the invention and use of techniques for the use of natural resources or for industrial activity", also defines an engineer as, "the person with a higher university degree that qualifies him to practice engineering in any of its branches". Chemical engineering is defined as the profession in which the knowledge obtained through the study, experience and practice of mathematics, chemistry and other natural sciences is applied in order to develop economic methods for the use of materials and energy for the benefit of mankind (Valiente Barderas, 1980), and is mainly aimed at the design and evaluation of equipment used in different industries. An engineer is considered to be a person who possesses the knowledge, values, skills and attitudes necessary to perform the work according to the applied standard (Valiente Barderas & Galdeano Bienzobas, 2014).

The Chemical Engineering career at the Central University of Ecuador has within its curriculum subjects oriented to the analysis of all types of substances, among them are analytical chemistry, instrumental analysis, organic chemistry, physics, chemistry, biotechnology, electrochemistry and others. Several procedures within these subjects are aimed at the analysis of biological and non-biological samples that are needed in the field of criminalistics.

On the other hand, criminalistics is a science that contributes to the analysis and investigation of crimes, through the laws of technical and natural sciences, by means of the collection and evaluation of forensic toxicological evidence, which can be of qualitative or quantitative origin. The methods generally employed by criminalistics are: observation, measurement, description, comparison and mainly the experiment (Hernández de la Torre, 2016). In Ecuador, the entity in charge of the analysis of samples of forensic services is the National Service of Legal Medicine and Forensic Sciences (SNMLCF) which has within its services the fields of forensic medicine, road accidentology and criminalistics, where the criminalistic service is in charge of executing the technical-scientific investigation to support before a prosecutorial accusation, within the areas of action are: ballistics, forensic chemistry, genetics, scanning electron microscopy, papiloscopy, among others (SNMLCF, 2007).

Criminalistics is supported by forensic science, which is a multidisciplinary science that is made up of different branches of study such as chemistry, geology, physics, biology, engineering, among others, as they are a very effective tool to give an accurate result on the investigation of a crime (Reyes Atuesta, 2016). A fundamental part of forensic science is forensic toxicology, this is a specialty in which toxicology is applied, that is, the science in charge of studying the effects caused by physical and chemical agents on animals and humans. (Roque, 2016), a very important characteristic within forensic toxicology is the need to collect, transport, analyze and store the samples in such a way that the chain of custody is guaranteed, (Drummer, 2010) that is, no one

is allowed to manipulate the samples or alter them in order to present reliable evidence before any court of law.

Another area of vital importance in criminalistics is forensic chemistry, since a chemist works with non-biological substances, such as glass, liquids, paint and traces of gunpowder resulting from a gunshot. In addition, a forensic chemist performs three main tasks, such as analyzing evidence in the laboratory, interpreting the information from the analysis and defending the information obtained before a court in the event of a trial (Valdebenito Zenteno & Báez Contreras, n/d).

ANALYSIS

An investigator dedicated to the laboratory area in criminalistics performs various procedures, and several analyses to the biological samples provided to get a positive result, which can be analyzed and presented. (Murillo Castaño & Vanegas Chaparro, 2015), among its primary functions is to isolate and identify drugs, poisons and other chemical compounds in human fluids and tissues that are related to the facts of a crime. (Roque, 2016).

The work of investigators can become complicated because some toxic substances do not produce any characteristic effect on the individual, which prevents a suspicion of a toxic reaction, so the methods of medical-legal research are studied in order to identify, determine and establish the substance that has produced the intoxication of the crime. (Barajas et al., 2020).

Toxicants studied by the analyst are classified according to their origin, physical state, target organ, chemical composition and mechanism of action (Murillo Castaño & Vanegas Chaparro, 2015).

The different toxicological tests performed for the analysis of drugs and different biological samples are done by gas chromatography (GC), high pressure liquid chromatography (HPLC) and various combinations with another technique widely used in the analysis which is mass spectrometry (MS) (Martínez González, 2014).

In the following, some analytical techniques of biological and non-biological materials, in which the knowledge acquired by a chemical engineer can be put into practice, will be explained, among them are:

- Forensic ballistics
- Study of hairs and fibers
- Fire and explosives
- Footprint analysis
- Forensic chemistry

Forensic Ballistics

Forensic ballistics is the science that studies the phenomena that occur inside the weapon, from the moment it leaves the muzzle until the impact of the bullet, also bases its study on the effects it produces in the body through a ballistic projection that will be used to substantiate a punishable act. (Cambres Jiménez & Castillo, 2015).

The tests that are performed in forensic ballistics are of two forms, physical examinations which are performed through the use of optical and measurement type tools, and chemical tests that are performed by observing the reactions of substances and materials (Torres Sierra & Medina Marulanda, 2018). There are several techniques to collect samples of gunshot residues, because when the shot is fired, combustion gases are produced that spread gunpowder grains of different sizes and shapes, and are lodged on the surfaces around where the event occurs. One technique used to determine gunshot residues is atomic absorption spectrophotometry, which measures the amount of energy by means of the

concentration of atoms absorbed by the elements to be analyzed. In this analysis, traces of lead, barium and antimony are identified, which are remains resulting from the handling of firearms (Bautista Hernández & Larico Laura, 2018). In general, bullets are also analyzed by means of criminological microscopes, where the marks that appear on the bullets are observed and compared, these marks are known as striae, it should be emphasized that when performing a visual examination there are errors, therefore, 3-D measurement techniques have been created, which allows the analysis to be more reliable in the topography of the surface of the bullets (Meneses & Contreras, 2009).

Silicone elastomers are currently being used to create replicas of bullet casings and projectiles, as this type of material has retractable, compression, stretching and rolling properties, this is due to the macromolecules by which they are formed as they deform and adopt an orientation in the direction of the force that is applied. The function of these elastomers in the field of forensic ballistics is that they allow establishing the participation of a firearm in different crimes committed, taking into account the ballistic traces left by the original weapon. (Miquelarena, 2019) Therefore, once analyzed the techniques used in forensic ballistics, it is determined that a chemical engineer can support due to his knowledge acquired in the analysis of atomic spectrophotometry, handling of microscopes, studies in physics and in the process of manufacturing polymers with different characteristics.

Study of hairs and fibers

It has been shown that hair analysis in post-mortem studies are important because they provide great forensic evidence due to its resistance to degradation, also maintains its characteristics along the type depending on the length of the hair. The metal adsorption capacity of hair depends on the acidity or the medium in which it is immersed, so it is suggested that hair acts as an ion exchanger, it should be noted that the concentration of metals determined by hair analysis can be incorporated through digestive, pulmonary and cutaneous exposure in addition to the external exposure suffered daily.

Hair has several advantages in the forensic field, as this type of sample cannot be physically altered like blood and urine samples, where concentrations of drugs and metals can be manipulated. Another important advantage is the ease of finding this sample as it can be found on the victim, on his clothes, in brushes, around the crime scene, etc. Among these we have the microscopic examination where the origin of the hair must be identified, that is to say, if it is of animal or human origin to later compare it with a standard, this is done by means of the observation in optical bridge microscopes. Then, there is the examination of the anatomy where the microscopic characteristics of the hair are observed mainly to know if the hair has been plucked or has fallen naturally (this type of examination is performed by an expert in the field), also through microscopy can determine the race of the person to whom the hair corresponds, as well as the sex through DNA analysis in the proximal area of the hair (Valdebenito Zenteno & Baez Contreras, 2007).

As explained above, there are different methods for hair analysis, but these analyses must be confirmed by analytical techniques, generally by means of mass spectroscopy (MS), gas chromatography (GC), high performance liquid chromatography (HPLC) and capillary electrophoresis. One of the combined

techniques for analysis is gas chromatography with mass spectrometry (GC-MS) where the sample is first subjected to GC where the compounds are separated according to their polarity and boiling, and then passed to MS where it is subjected to different types of ionization, such as electron impact ionization, chemical ionization and electrospray ionization.

Another technique is HPLC-MS, this technique allows to face the disadvantages of the GC-MS technique, but it is used to a limited extent due to its high operational cost. Finally there is capillary electrophoresis (CE) which is a technique for separation and identification of xenobiotics in hair, this technique operates in two modes: capillary zone electrophoresis (CZE) and micellar electrokinetic capillary chromatography (MEKC), has disadvantages due to moderate sensitivity so it is coupled with mass spectrometry obtaining considerable advantages, because on the part of the CE is obtained efficiency, speed, use of small amounts of samples, on the part of the MS is obtained its high sensitivity and selectivity. (Oliviera Gordo, 2013)

Fire and explosives

An explosive is defined as a substance or mixture of substances, which produce an exothermic chemical reaction that can be initiated by friction, impact, shock, electrical discharges or heating, producing a large amount of energy that is released in the form of light, heat, sound waves or gas thus exerting high pressures around it. A characteristic that must be fulfilled for an explosion to exist is the local accumulation of energy at the site of the explosion, the energy released in the explosion is dissipated in the form of shock waves, propulsion of debris, or by the emission of thermal or ionizing radiation, which cause serious damage to material things and human beings. Explosives have many classifications, but the analytical techniques used in explosives will be analyzed according to their potency.

Low power explosives are those that burn at a speed of several meters per second, these are used especially for fireworks, among these explosives we have gunpowder, pyrodex, gold dust, among others. For the analysis of low-power explosives, the oxidant and fuel must be determined in the first instance by systematic analysis, then by visual and microscopic analysis it is determined whether the explosive is composed of a single component or a mixture of these, in case of being a mixture, the compounds can be separated by solvent extraction or mechanically by means of a microscope.

Once separated, the relevant analytical techniques are carried out. Thin layer chromatography (FLC), infrared spectroscopy (IR) and X-ray diffraction are used for this type of explosive. CFF is a widely used method in explosives analysis as it is an accepted method of scanning for organic explosives, particularly for post-explosion residues. IR is a technique used to determine unreacted organic oxidants, organic fuels and base compounds in mixtures in this type of explosives, due to the fact that there are elements that change their absorption frequencies when bound with water, it is recommended to complement this technique with elemental analysis of components and residues. In X-ray diffraction crystalline components are identified in inorganic mixtures, being a non-destructive method, compounds are identified, especially pure compounds, the results obtained with this technique are compared with a standard depending on the case. (Suarez Ramirez, 2014).

Fingerprint analysis

In criminalistics it is important to analyze

fingerprints, these can be from teeth, face, hands, feet, tires, tools, etc., these prints must be analyzed in a very meticulous manner, since the results of the techniques used will provide significant evidence before a court.

- Bite analysis: These analyses are performed by forensic dentistry, this type of analysis is important because bite marks can be found in both victims and perpetrators, as it can be used as an instrument of defense or aggression. There are several different methods to analyze bite marks, among those are dental models, wax bite registrations, photographs and computer programs that scan the images (Jaramillo Quiroz, 2019).
- Analysis of lipstick: The analysis of lipstick is performed by chromatographic, spectrophotometric, fluorescent and other techniques, these are analyzed from the pigments, waxes and fats found in the composition of lipsticks. Lipsticks leave traces that can be duplicated by means of lip prints and cheilograms, and they can also be analyzed by means of their composition because each lipstick changes due to special substances that each company adds for its sale, such as colorants, perfumes and a base (Alvarez Seguí, 1999).
- Footprint analysis: This analysis is performed by means of physicochemical tests, which help to study the footprints found at the crime scene, to later compare them with the suspects' footwear. This type of test is based on an electrostatic procedure, which allows to make a modeler either if the footprint is very accentuated or cannot be detected with the naked eye, this will allow the persons in charge to have an important evidence that supports and contributes before a judge (Valdebenito Zenteno & Báez Contreras, n/d).
- Fingerprint analysis: The results of a fingerprint are very difficult to question, this is because the fingerprint of an individual allows to identify the identity of this, there are different ways to find and reveal fingerprints, to find a fingerprint techniques that require reagents that stick easily to these are used, Among the most popular are the powder type, these types of powders are very effective because they stick to the prints by the oily and greasy composition that have the fingers of people, there are also magnetic powders, fluorescent, among others. (Reyes Atuesta, 2016) Depending on the type of place the above mentioned powders are used, in the case of the powdery type they are used on surfaces of materials such as glass, metals and plastic, magnetic powders are used on surfaces such as leather, wood or paper, and fluorescent powders are used with the help of an ultraviolet light that causes the powder to shine and leave the sample in evidence. (Valdebenito Zenteno & Báez Contreras, n/d).

Forensic chemistry

As explained above, forensic chemistry is a science that involves knowledge of physics, chemistry, biology, mathematics and other sciences, which helps through scientific evidence in criminal investigations. Forensic chemistry presents different analyses within its wide variety of manifestations such as:

- Drug test: Through this test it is possible to identify and quantify the amount of drugs present in the sample taken from the individual, they are analyzed taking into account two important aspects, the physical evidence and the biological evidence either in living or deceased individuals (Reyes Atuesta, 2016). Currently, samples are searched for the presence of drugs in any of their forms of presentation (powders, liquids, tablets or capsules). These analyses are performed by mixing antibodies of certain drugs with the

metabolites of the individual's sample, where a result is obtained based on the degree of sensitivity (Valdebenito Zenteno & Báez Contreras, n/d).

- Detection of semen stains: There are different analytical tests to analyze semen stains, first to find these stains ultraviolet light techniques are used, because this type of stains fluoresce directly under the action of ultraviolet radiations, another test are microscopic tests where it is determined how recent the stain is by observing the spermatozoa, The electrophoretic method is based on a two-dimensional method that allows the separation of specific amino acids, in this case spermine, by combining electrophoresis and chromatography techniques. Finally, there is the enzymatic method that determines the amount of acid phosphatase present in the sperm. Staining techniques such as Gram staining and Crystal Violet Staining are also used (T. Lopez, 2013).
- Detection of blood stains: Blood is one of the most important evidences of a crime, this type of stains are analyzed through different qualitative techniques due to the presence of peroxidases in the blood that react with some chemical agents that cause them to change color, that is, colorimetric techniques are used (Valdebenito Zenteno & Báez Contreras, n/d).

Each colorimetric technique produces different reactions with bloodstains and they manifest themselves in various colors depending on the technique:

> Adler's technique: Hemoglobin in the blood by means of peroxidase enzymes decomposes hydrogen peroxide into water and oxygen, which when in contact with benzidine causes an oxidation reaction that will be revealed by an intense blue coloration (Aparicio, 2017).

> Kastle-Mater technique: In this technique phenolphthalein is used which must be in an acid medium to remain colorless, peroxidase reactions are similar to the Adler technique, with the difference that the coloration presented is fuchsia because it works in an alkaline medium, this technique can detect blood stains after several months after the crime occurred. (Aparicio, 2017).

> Green leuco malachite technique: It is based on oxidation-reduction reactions as the previous techniques, the reagent is treated to remain transparent and when in contact with the blood stain it turns green, this technique allows to check old samples up to 80 days old.(Aparicio, 2017).

Once the bloodstain is detected, it is checked by spectroscopic techniques which by means of absorption spectra detect the presence of hemoglobin and compare it with its respective visible spectrum (Aparicio, 2017). There are other confirmation techniques which are:

> Teichmann or Hematin crystals: This technique by means of an oxidation process of hemoglobin and the prosthetic group treated with acetic acid forms insoluble crystals of hematin chloride, due to the presence of some halogen present in the sample (Castellanos Sainz, n/d).

> Takayama or hemochromogen test: The heme group, present in hemoglobins, combines with other nitrogen groups called hemochromogens forming crystals, this process can occur in acid and alkaline media (Castellanos Sainz, n/d).

> Precipitins by immunoelectrophoresis: By means of the electrophoresis technique, the antigen migrates towards the anode and the antibody towards the cathode through a plate with perforations, once the process is finished, precipitation bands are observed as a result of

the protein groups that react (Castellanos Sainz, n/d).

- Qualitative analysis of narcotic substances: This type of analysis is performed using the technique of gas chromatography coupled to mass spectrometry (GC-MS), this technique is very safe because the spectra of the samples are compared with known patterns avoiding any type of failure, and allowing the detection and confirmation of any substance within the victim's sample.(Gandur Torrado, 2016)

CONCLUSION

Through the present work and by means of the information collected, it was determined that analytical techniques such as colorimetry, spectrophotometry, chromatography, microscopy, among others, which are used in different analyses in forensic science and crime laboratories, are also present in the training of a chemical engineer, Therefore, they can be considered a support that at a given time can contribute significantly in different areas since the knowledge and criteria acquired in their professional life allows them to examine, confirm and conclude according to the results obtained, it should be emphasized that they can become a support for the person in the area of forensic chemistry to issue a criterion and the final result when evidence needs to be presented before a judge.

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