EVOLUTION OF GREEN CHEMISTRY AND ITS IMPACT ON HUMAN LIFE

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Abstract. The growing process of industrialization was a milestone for world economic evolution. Since the 1940s, social movements have revolutionized green chemistry and provided shifts in industrial positions and sustainable processes with advances in environmental impact and awareness of companies and population. Paul Anastas and John Warner, in the 1990s, postulated the 12 principles of Green Chemistry, which are based on the minimization or non-use of toxic solvents in chemical processes and analyzes, as well as, the non-generation of residues from these processes. One of the most active areas of Research and Development in Green Chemistry is the development of analytical methodologies, giving rise to the so-called Green Analytical Chemistry. The impacts of green chemistry on pharmaceutical analyzes, environmental, population, analyst and company are described in this review and they are multidimensional. Every choice and analytical attitude has consequences both in the final product and in everything that surrounds it. The future of green chemistry as well as our future and the environment is also contemplated in this work.

Keywords: Green Chemistry, Green Analytical Chemistry, human impact, perspectives of Green Chemistry.

Introduction. Since the 1940s, environmental issues began to emerge in relation to the growth of industrial activities. In the face of environmental problems and concerns, companies have changed their position on conventional production and product development habits through conferences, political agreements and advances in chemical research and ecological engineering adopting sustainable processes to the present.

In the 1990s, Paul Anastas and John Warner postulated the 12 principles of Green Chemistry, still in use today, that rely on the minimization or non-use of toxic solvents in chemical processes and analyzes, as well as the non-generation of wastes from these processes. These principles propose environmentally favorable actions from the planning of the product to its synthesis, processing, analysis and its destination after use. The main objective is to minimize the environmental and occupational hazards inherent in industrial activities [1, 2].

Later, Paul Anastas discussed the importance of using these 12 principles in the development of new methods and analytical techniques, with the purpose of reducing their environmental impacts (Anastas, 1999). Thus, one of the most active areas of Research and Development in Green Chemistry is the development of analytical methodologies. New methods and techniques that are able to reduce the use and generation of hazardous substances in all stages of chemical analysis are the main goals of the so-called Green Analytical Chemistry [3-5]. In this context, Galuszka, Migaszewski and Namienski, in the year 2013, adapted the 12 principles of Green Chemistry, to better fit the Green Analytical Chemistry.

The impacts of green chemistry are multidimensional. Each analytical choice has consequences both in the final product and in everything that surrounds it, from the environment, population, analyst and even the company.

Cathcart [6], who presented a discussion on the growth of the Irish chemical industry, probably used the term “Green Chemistry” for the first time in a paper title in the year 1990. However, only in 1996, the first publication, by Anastas and Williamson, approached Green Chemistry with the philosophy adopted today [6, 7].

The main concept of Green Chemistry is the use of chemical skills and knowledge to reduce or eliminate the use or generation of hazardous substances during the planning, manufacturing and application of chemicals in order to minimize threats to the health of operators and the environment [8]. Thus, the concern to eliminate or minimize the generation of toxic waste has become greater than treating the waste already generated.

In 1999, Paul Anastas published a paper in which he discussed the importance of using the 12 principles of Green Chemistry, postulated by him and John Warner in the previous year (1998), in the development of new methods and analytical techniques, in order to reduce their environmental impacts [8]. One of the most active areas of Research and Development in Green Chemistry is the development of analytical methodologies. New methods and techniques that are able to reduce and eliminate the use and generation of hazardous substances in all stages of chemical analysis are the main targets of the so-called Green Analytical Chemistry [3, 4, 8, 9].

The principles suggested by Galuszka, Migaszewski and Namiénski are based mainly on the elimination or minimization of the use of chemical substances, on the minimization of the consumption of electricity, on the correct handling of the generated analytical residues and on the greater safety of the operators [10].

The aim of the study. Investigate the impact of environmental chemistry on pharmaceutical analysis, the environment, the public, analysts, and the company.

Materials and Methods. We used scientific and popular science publications that reveal one of the most active areas of research and development in green chemistry

- the development of analytical methodologies - and show the promising development for the future of environmental chemistry and its impact on the environment.

Results and Discussion. Currently the chemical-pharmaceutical industries and laboratories must contemplate green chemistry through, and not only, their analysis. The chosen method, reagents, accessories, personnel qualification, time to evaluate the quality of a product are part of the ecologically correct thinking [11].

The method of choice for the determination of active pharmaceutical ingredients as well as the investigation of impurities and degradation products is high performance liquid chromatography (HPLC). Most of these methods use as organic solvents, acetonitrile and/or methanol. Many also opt for buffer solutions. This is indisputable. However, most of them have never even attempted to use another organic solvent in addition to the acetonitrile/methanol combination or do not use buffer solutions in the mobile phase [12-17].

Buffer solutions, in addition to requiring a certain amount of time to prepare, have a low shelf life which requires a new preparation and thus a longer dispensing time. The use of it also requires an extensive cleaning process of both the column and the entire chromatographic system [18].

Toxic organic solvents, such as acetonitrile and methanol, in addition to damaging the health of the operator who is exposed daily to these solvents also requires proper waste management for the disposal of this contaminant. This has a cost that will certainly be included in the final product [13].

Even the accessories used in the methods of analysis can contemplate green thinking. Chromatographic pre-columns are often not needed, but are used by lack of knowledge of the analyst who understands that it must be present. Steps, that are not necessary but, which are carried out by lack of knowledge of the analyst who understands that if he does not do it the method will be incorrect and will lead to a result out of specification. Devices that can be reused but that are not because the company always buys more and so it is more convenient to throw away and wait for the new one to arrive [8, 19-22].

Often qualified personnel are assigned to develop banal tasks, repetition of tasks such as a robot, over processing products and processes rather than develop, create, and evolve within their work area. This is a waste of intellect, one of the eight wastes we have today. It is a sophisticated and qualified workforce hired to perform mediocre services. Is the time for each process or analysis measured? It must be. It is part of green chemistry. The longer an activity takes, the longer the analyst will need to be dependent on it and fewer activities he will develop and therefore there will be less production and the final product will be more expensive. Time, an item that starts an entire process or service, has direct consequences on the final product [16].

The residues generated in the chemical-pharmaceutical analyzes must be pre-treated before being returned to the environment. However, this process requires a cost that is more expensive depending on the toxicity and hazardousness of the solvent.

Acetonitrile, for example, is incinerated and this process generates waste that contributes to acid rain. Even using a process to neutralize the toxicity of the solvent, it negatively affects us otherwise. Acid rain damages cars, buildings, monuments, vegetation, rivers, lakes and so on.

The vegetation can contemplate plantations that feed thousands of people. The waters can be affected with a lower pH and change the habitat previously favorable to certain organisms that lived there. An effect like this will never be isolated! This is when waste is treated, but when are not? When industrial wastes are dumped directly into the waters ecological disasters can occur. Fish and vegetation die, contaminated water changes its characteristics and eutrophication occurs. In some cases this water would be used for the irrigation of plantations, which in this case would also be impaired.

The population is impacted by current chemistry in different ways and on different fronts. Patients who frequently get their medication from pharmacies or health centers are affected by the choice of methods of analysis and reagents used by analysts or chemical-pharmaceutical operators. An expensive method generates an expensive product on the market. An expensive method with accessories (not always necessary) generates a more expensive product on the market. An expensive method with accessories and several steps (not always necessary) generates an even more expensive product on the market [20].

A time-consuming method that releases results within 24 h or more, such as microbiological results for antibiotics, will make products expensive or, if released without this analysis, perhaps inefficient which can promote the overload of the health system and contribute to microbial resistance [11, 18, 23-30].

The patient is undoubtedly affected by the analytical decision in the analysis of a pharmaceutical, in the evaluation of the quality of a raw material and in the development of an industrial or laboratory process [31].

Chemical-pharmaceutical companies must increasingly contemplate the principles of green chemistry and/or green analytical chemistry, since switching off the light until choosing the reagent to be used in the evaluation of a pharmaceutical, since the interaction with the collaborator until the provision of training for a team.

Green chemistry must be seen as a sustainable idea since a better world until a better company, people and conviviality. A company that values this kind of attitude, modern and current, will certainly succeed. In it there will be no employees but collaborators. In it there will be no chief but leaders. In it there will be no the vision only in the final product but in the whole chain, in order to be sustainable, green and clean [32-34]. Thus, automatically, the company grows. The vision of the company is also benefited, because it becomes a model and reference of the ecologically correct, clean and sustainable, besides being competitive in the market. Companies like Coca-Cola™, Google™, Apple™ are examples of this concept [35-37].

Conclusions. Research advances have enabled sustainable processes over the years with investments in environmentally correct analytical and policy techniques in line with world conferences since 1968. Despite these efforts, industries need to visualize the economic viability of applying green chemistry to their processes, which prevents us from leveraging the use of this ideology. Investments and dissemination on the importance of green chemistry and how they affect directly from the start of pharmaceutical analyzes, employees and patient health until to the environmental sustainability are extremely important for the process of future improvements.

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