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RISK ANALYSIS CONSIDERING ACCIDENT IN NUCLEAR REACTORS AND OIL REFINERIES

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ABSTRACT

Risk analysis is an important tool to help decision-making, especially related to energy choices and their environmental consequences. This paper sets out to analyze the risk associated with deploying and operating a nuclear installation for later comparison with the risk of other energy sources such as oil. We have conducted a risk analysis based on the number of reactors-year and the number of worldwide accidents that have occurred in nuclear power plants. The same was done based on the number of refineries-year and the number of accidents that have occurred worldwide in oil refineries. Our results showed that the risk of accidents in nuclear power plants is smaller than the risk in oil production. We believe the proposed analysis might affect the decision-making process in the environmental area and contribute to a more sustainable energy future.

1. INTRODUCTION

The risk assessment of a system consists of the use of all available information to estimate the risk to individuals or populations, property or the environment, from identified hazards, the comparison with targets, and the search for optimal solutions [1].

When a risk analysis is performed, it is important to realize that decision-making about risks is very complex and that not only technical aspects, but also economical, environmental, political, psychological and societal processes play an important role [1].

A risk analysis generally contains the following steps: scope definition, hazard identification, modeling of hazard scenarios, consequence estimation**,** probability estimation and risk estimation. The first three steps of the risk analysis are considered the qualitative part, the last three steps risk analysis make up the quantitative part [1].

The advantages of a risk-based approach include the following: it takes probabilities as well as consequences into account; it provides a basis for comparing the effects of different scenarios in terms of significance; it integrates the effects of all types of scenarios. Some disadvantages can also be mentioned: the concept of risk is not easy to grasp; it is difficult to assign values to the probabilities; people may attach greater significance if higher doses are possible even though the probability of occurrence is very low [2]. That is, risks are relative and so is the perception of people about them.

In recent years there has been a renewed interest in nuclear energy as an option to the future's energy source both in developed and developing countries. However, the contribution of nuclear power to a sustainable energy future is a contested issue. The controversial nature of this issue may be related to a series of interrelated factors such as: the complexity of the relevant facts to the analysis and the plurality of positions, values and challenges that are at stake [3].

This paper sets out to identify and analyze risks associated with deploying and operating a nuclear installation and compare them to the risks related to oil production. Such comparison is justified by the introduction of electric vehicles in the light passenger vehicles market and by the belief that a greater dissemination of this technology is not far. In this context, our objective is to see how the risk analysis fits into decision-making process concerning its choice as a source of electric power generation.

2. NUCLEAR REACTORS

Currently there are 433 nuclear reactors operating worldwide, spread out among countries heterogeneously. In France, there are 58 reactors in operation, 104 in the United States and 32 in Russia. In Brazil, there are now two reactors in operation and one under construction [4].

This country has comparative advantages to nuclear power, associated with uranium reserves and fuel production technology. Due to the Nuclear Non-Proliferation Treaty policies, the development and transfer of technology related to fuel cycle became highly restrictive, thus emphasizing the importance of mastering this technology to the country [5].

Over the decades, nuclear safety has been improved, in order to reduce the likelihood of failures and accidents with serious consequences. International Agreements managed by the IAEA ensure that experiments and new demands are met by all countries [6].

The main disadvantages associated with nuclear power are related to environmental risks, which are a source of concern for environmentalists, and spread to society as a whole. These risks can be broken down into four aspects: risks during plant's normal operation, risks in case of accident, fuel cycle risks, and risks in storage of waste [5].

In light of these risks, nuclear installations are built aimed for maximum safety, in order to avoid any release of radioactive material into the environment. This is done through a series of systems, operational measures and physical barriers are set to ensure no setbacks [7]. An important feature related to safety comes from the standardization of reactors, which facilitates the identification of hazard sources and enables data and figures from previous studies to be common to all reactors of the same type [8].

The advent of nuclear installations cooperated with the development of risk analysis. Accidents associated to nuclear plants are of low frequency, but they can bring catastrophic consequences, being classified as installations of high potential risks [9].

3. OIL

Another widely used energy source in the world is oil, as it is used for various purposes, it has in its production chain a series of impacts and risks to the population.

In order to get fuel for vehicles from oil, it is necessary to refine it [10]. This process is very capital-intensive and covers different stages that culminate in a complex system of multiple operations [11].

A series of impacts and environmental risks can be associated to an oil refinery. Pollution is a major environmental problem and the risks of accidents such as fire, explosion or leakage constantly permeate these facilities [10].

4. METHODS

In the book "Should we risk it?" [12], Kammen and Hassenzahl developed a risk analysis which compared the amount of reactors-year to the amount of accidents involving nuclear facilities to estimate the probability of a major release per reactor-year. The following risk analysis comes from the model developed by the authors.

The steps for conducting a risk analysis for nuclear power were as follows:

1. Identify the number of existing reactors in 2011;
2. Verify the age of each one of them;
3. Calculate the reactors-year figure (base year 2011);
4. Identify the number of accidents over the 41-year history of nuclear power;
5. Calculate the odds of an accident per reactor-year;

The steps for conducting a risk analysis for oil energy were as follows:

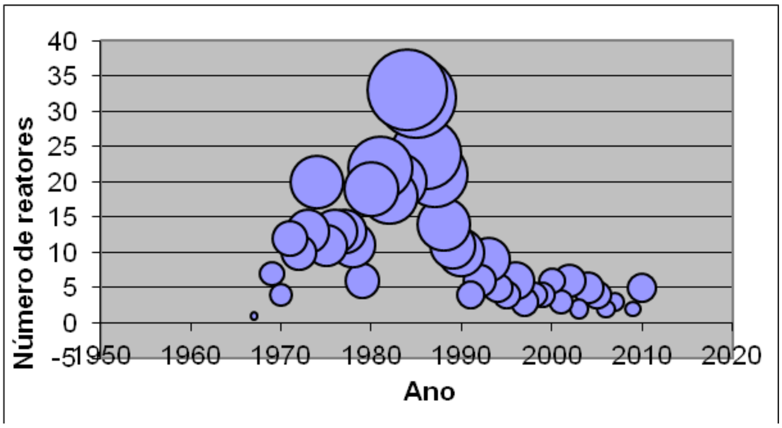
1. Identify the number of existing oil refineries in 2011;
2. Calculate the refineries-year figure;
3. Identify accidents which occurred over the past 41 years in oil refineries;
4. Calculate the odds of an accident per refinery-year;
5. Final comparison between the odds of a nuclear accident and an accident related to oil production.

The operation of major nuclear power reactors started around 1970, and today there are approximately 433 nuclear reactors in operation in the world [4]. Considering the 433 existing reactors, the value of 11,249 reactors-year was obtained (appendix), by multiplying the age by the number of nuclear plants and adding the corresponding results, as shown in equation 1:

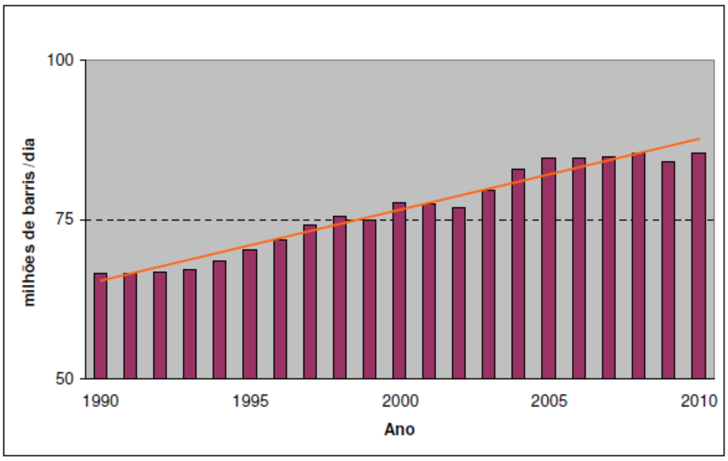
$$\text{Sum of the number of nuclear power plants x age = reactors-year figure.} \qquad (1)$$

Graph 1 shows the number of units and the years they were being built in the y and x axes, respectively. The bubbles represent the power of the plants installed in that year, in MW, which are proportional to the size of the bubbles.

It is possible to observe a trend from plants and their power, since older plants are less powerful than the ones of intermediate age. On the other hand, the newer ones are also less powerful, meaning fewer projects, with less installed power per year. We can deduce that the interest in nuclear power has diminished over the past years. Conversely, the use of oil energy has been growing in recent years, as shown in graph 2.



Graph 1: Numbers of installed reactors, age and additional power per year.



Graph 2: Oil production in million barrels a day from 1990-2010.

Over the period of 41 years, there were three major accidents involving nuclear reactors: the Fukushima's, Japan, on March 2011; Chernobyl's in 1986, and the Three-Mile Island's in 1979. On this basis, the approximate likelihood of a major release per reactor-year is 26 in 100,000. This value is obtained by dividing the number of accidents by the reactor-year ratio, as shown in equation 2:

Accidents in nuclear reactors occurred in the period in question/value obtained from reactors-year= approximate likelihood of an accident in a nuclear reactor per year. (2)

There are 657 refineries of crude oil in the world [13]. In literature were reported 397 accidents in refineries [14]. Considering that the first accident was documented in 1970, the considered age of all the refineries was 41 years. Thus, multiplying the number of existing refineries by their age, the result is 26,937 refineries-year, as shown in equation 3:

$$\text{Sum of the number of refineries X Age = refineries-year} \quad (3)$$

Thus, by dividing the number of accidents in refineries by the refineries-year figure, the result is 0.014 or 14 in 1.000, which represents the likelihood of accidents for each refinery per year, as shown in equation 4:

$$\text{Accidents occurred in refineries during the period considered/refineries-year figure = approximate likelihood of accident occurrence in a refinery per year} \quad (4)$$

5. RESULTS

The first results obtained are related to the likelihood of a nuclear accident, which is 0.00026 per reactor-year, or 26 in 100,000.

A similar analysis was carried out for oil production, showing that both gas produced from oil and the electricity produced by nuclear power plants can be used as fuel for cars. The results show the probability of an accident at a refinery per year, which is 0.014 per refinery-year or 1,400 in 100,000.

The data obtained based on oil production analysis showed a value of $1.4x10^{-2}$ to the likelihood of accidents in all refineries per year. This value is much higher when compared to accidents related to nuclear facilities ($2.6x10^{-4}$), where the first one is two orders of magnitude higher than the second one.

6. DISCUSSION

The results from this analysis show that the risk of a nuclear accident is significantly low when compared to the risk of accidents related to oil production (two orders of magnitude lower). However, when we think about the number of casualties, accidents in nuclear power plants have much worse long term consequences, which are often difficult to measure.

Some assumptions of the method led to the presented result, such as considering the age of all refineries as 40 years old, since the first documented accident was in 1960, also it would be impossible to determine the age for each existing refinery in the world.

It should be also noted that this risk analysis, as any similar analysis, deals with probabilities, leading to very variable values, which differ according to the proposed approach. Therefore, it is very important to demonstrate the data from risk analysis in a clear manner, so that the results are not only known, but also identified and understood through the ways and methods that led to them.

7. CONCLUSIONS

This paper allows us to conclude that the risk associated to nuclear energy is much smaller than the one associated with oil production, when we deal with the number of accidents related to each energy source.

Studies like this can be used to prevent and mitigate harmful consequences of accidents in high complexity projects. Its value to society lies in the possibility of accepting the sharing of risks, as well as its reduction and mitigation of consequences of accidents by setting standards and improving the reliability and safety of technological systems.

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