Assessment of Biofuel Accident Risk: A Preliminary Study

Selva S. Rivera, Romina D. Calvo Olivares, Pedro A. Baziuk and Jorge E. Núñez Mc Leod, *Members, IAENG*

***Abstract*—This work presents a study of accidents with fatalities in biofuel industries. The objective is to present preliminary accident risks associated with biodiesel and ethanol plants. The analysis is based on data occurring from 2003 to November 2013. Data statistical analysis shows that the frequency of accidents in biofuel plants has an increasing tendency, being fires and explosions the main type of accidents that occurred.**

***Index Terms*—accidents, biofuel, biodiesel, ethanol**

I. Introduction

RISK is a multi-attribute quantity expressing hazard, danger or chance of harmful or injurious consequences associated with an actual or potential event under consideration [1].

The objective of this study is to present preliminary accident risks associated with the biofuel sector.

The analysis of accident risks is based on data occurring from 2003 to November 2013.

The approach used in this study was based on the evaluation of experience with accidents in the past. It is related to the collection of data from different documental sources and the subsequent setting of a database containing general information about adverse events, its consequence, mitigation, causes, and human, environmental and material consequences occurred in biodiesel facilities during the last years. Registered events comprise facilities in United States, Canada, Australia, Malaysia, Brazil, Argentina and some European countries.

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The biodiesel and ethanol accident databases were built through the revision of the following sources [2], [3]:

-- Occupational Safety and Health Asministration (OSHA).
-- Industrial Fire World.
-- Biodiesel Magazine.
-- Biofuels Journal and Grainnet.
-- Steel Tank Institute.
-- Environmental Protection Agency of United Stated.
-- Articles in academic journals.
-- Newspapers.
-- Ethanol Producer Magazine.

The focus of the study remained on accidents with fatalities. Comparative analyses of biodiesel and ethanol industries were performed, using aggregated indicators and frequency-consequence curves.

II. Nature of Data Collected

The data collected were based on [2] y [3].

A total of 211 events were registered and 19 accidents with fatalities were founded (12 Accidents from biodiesel / 7 from ethanol) as is shown in Fig. 1.

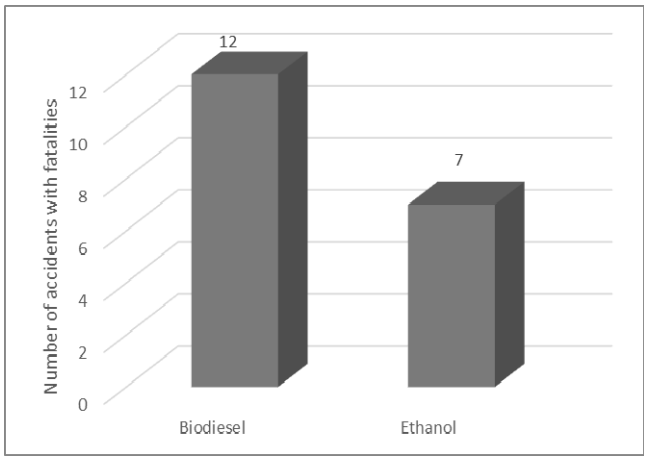

Fig. 1. Overview of the number of accidents for biodiesel and ethanol industries, with fatalities, in the period 2003 to 2013.

Fig. 2 shows the number of fatalities worldwide in biodiesel (17 fatalities) and ethanol (8 fatalities) accidents over the time period of 10 years.

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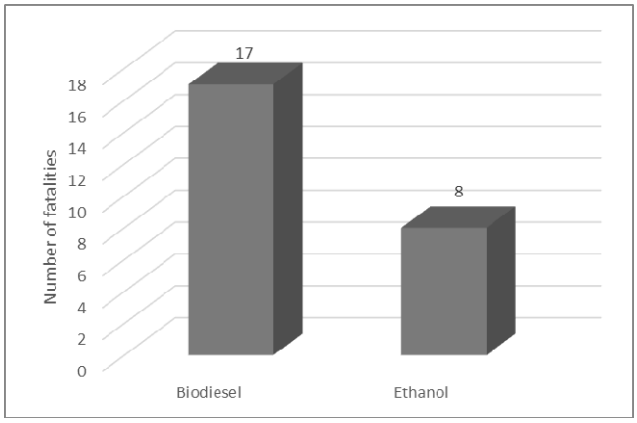

Fig. 2. Overview of the number of fatalities for biodiesel and ethanol industries with fatalities in the period 2003 to 2013.

III. Statistical Information

Available information on accidents with fatalities in the period 2003 to 2013 is summarized in Tab. 1.

Evaluations and analyses were focused on fatalities and aggregated indicators reveal some general trends.

TABLE I
NUMBER OF ACCIDENTS WITH FATALITIES AND CORRESPONDING FATALITIES

	Biodiesel		Ethanol	
year	**Number of accidents**	**Number of fatalities**	**Number of accidents**	**Number of fatalities**
2003			**2**	3
2004				
2005				
2006	**1**	1		
2007	**1**	1	**1**	1
2008	**4**	6		
2009	**2**	4	**2**	2
2010	**1**	1		
2011	**2**	3	**1**	1
2012	**1**	1		
2013			**1**	1

The number of total accidents and accidents with fatalities in the world are shown de Fig. 3.

Ethanol and biodiesel accidents with fatalities are similar in number. The higher number of accidents was in 2009. Ethanol has the higher number of fatalities in 2008.

The survey of 86 adverse events occurring at biodiesel plants shows that accident frequency grew up to 2009.

In the following three years it has remained with a decreasing and increasing oscillatory behavior.

In 2013 there is a worrying situation: during the first five months there were seven incidents (only one less than the previous year's total) although none of them with fatalities.

The major number of fatalities was in 2008 and the highest number of injured people was registered in 2012.

The survey of 121 adverse events occurring at ethanol plants shows that accident frequency grew up to the year 2009, when it reached the highest value.

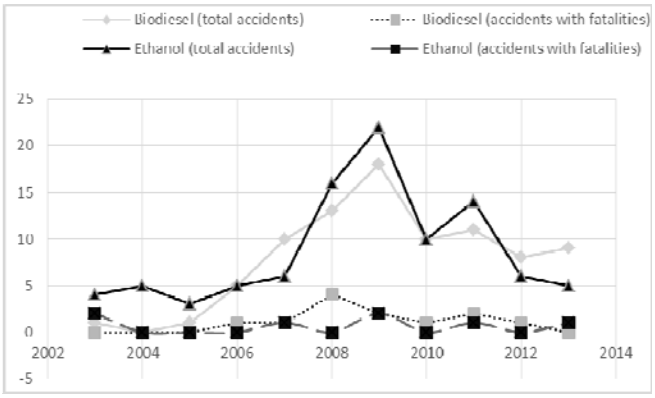

Fig. 3. Number of total accidents and accidents with fatalities for biodiesel and ethanol industries per year in the period 2003 to 2013.

During the following five years it has remained with a decreasing and increasing oscillatory behavior.

The distribution of accidents per year has to do with more availability and a better access to information and not necessarily with an increment of accidents rates.

Accidents in biofuel plants have an increasing tendency, being fires and explosions the main type of accidents that occurred.

IV. Severe Accident Risks

Disasters and accidents occur as a consequence of the impact of a natural or man-made hazard. They increased in the last decades. This trend has been recognized by different stakeholders, including the reinsurance business and international organizations, and likewise leads to increases public attention through the media [4].

Fuels derived from biomass are being developed as a renewable source of energy and the investment in biofuel production is growing. Unlike a typical hydrocarbon fuel production process, most of the biofuel production methods are simpler raising the number of plants and new operators that result in a number of incidents and accidents with loss of life and properties [29].

The approach used in this study was based on the evaluation of experience with accidents in the past.

The definition of what constitutes a severe accident will relate in this work to 1 or more fatalities.

V. Frequency and Severity

It is commonly believed amongst biofuel manufacturers that process safety can be achieved by common sense. Expertise is needed to identify and manage biofuel manufacturing risk [29].

Due to it is a simple chemical process, safety frequently is omitted and it is important to note the lack of training in safety of the personnel. Authors [11] recommend doing Failure Mode and Effect Analysis in order to improve the safety and to diminish the human error.

Risk can be decomposed into the product of the frequency and severity. The number of accidents per year gives the frequency, while severity measures the extent of the consequences of each accident [5], [13], [14], [15].

In this work, the number of fatalities describes severity.

Frequency distribution is shown in Fig. 4.

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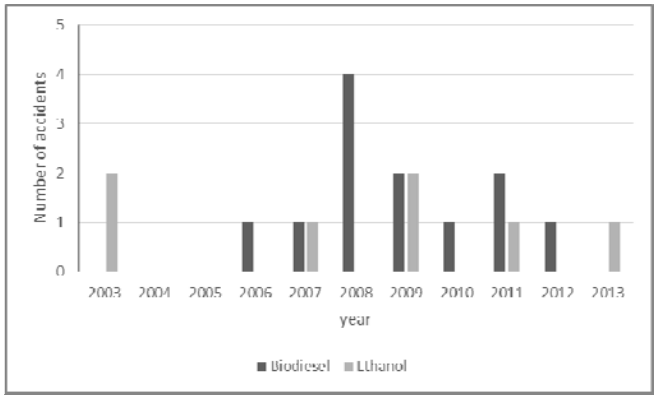

Fig. 4. Number of accidents with fatalities for biodiesel and ethanol industries per year in the period 2003 to 2013.

A comparative number of accidents with fatalities for biodiesel and ethanol industries show in 2008 no had accidents related with ethanol but biodiesel had the higher number of both industries.

Fatality distribution is shown in Fig. 5.

The higher number of fatalities was in 2008 when there was the higher number of accidents.

Frequency and consequence are taken into account when the hazard is assessed.

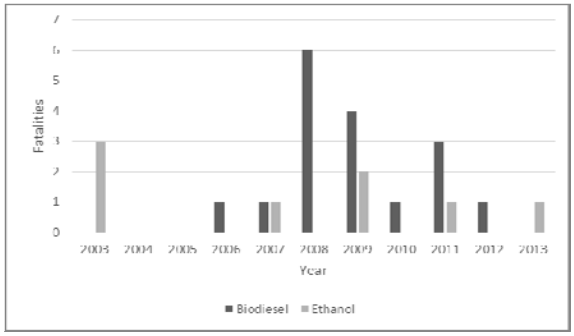

Fig. 5. Number of fatalities for biodiesel and ethanol industries per year in the period 2003 to 2013.

The relationship between fatalities and accidents is shown in Fig. 6. Biodiesel industry has almost 1 accident per year.

To mitigate consequence it is necessary to reduce the vulnerable area that accident scenarios create and in doing so, reduce the number of people exposed and consequently the expected number of deaths.

The usual action to mitigate a consequence it is to change the product or reduce the volume of product. To mitigate frequency it is necessary to reduce frequency values [6].

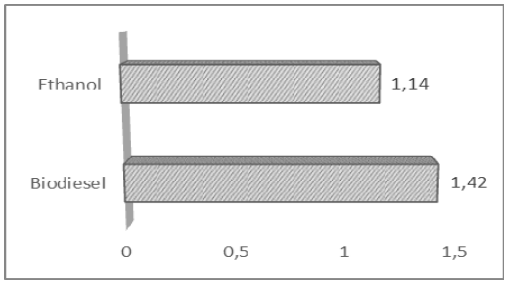

Fig. 6. Number of fatalities / accidents for biodiesel and ethanol industries per year in the period 2003 to 2013.

The share of fatalities in biodiesel industry was 14% and 7.3% in ethanol industry.

VI. Frequency-consequence curves

Biodiesel is an alternative fuel that can be used in pure form or mixed with petroleum- based diesel, with little or no adequacy of engines. It has also environmental advantages such as reduction of carbon emissions.

These advantages added to the global perspective of exhaustion of fossil fuels, and the consequently searching of new alternative energy sources has produced a significant increase of production of biodiesel, in particular during the last decade.

As occurred with biodiesel, the exhaustion of petroleum reserves, the need of diminishing dependence on fossil fuels and deal with climate crisis made ethanol production grow up exponentially, mainly after the year 2000.

Immediate causes of accidents in biodiesel industry in period 2003 to November 2013 are:

- equipment-mechanical failure
- human factor-operator error
- external event
- ignition by electric sparks
- spontaneous combustion
- autoignition
- other causes

Consequences of accidents and incidents are:

- communities disruption
- ecological harm
- injuries
- fatalities
- partial material loss
- other consequences

Immediate causes of accidents in ethanol industry in period 2003 to November 2013 are:

- equipment-mechanical failure
- ignition of corn-dust

Respect to equipment-mechanical failures, the most common are failures in the dryer during production of coproducts and valve failures.

Human error has a little contribution as well as ignition by electric sparks and spontaneous combustion.

Consequences of accidents and incidents are;

- release of hazardous vapors/spill of liquid substances inside the plant
- minor structural damage and no injured people
- <10 injured people and/or important structural damage
- >10 injured people and/or environmental harm
- Total loss of a building installation or equipment
- dead people

In previous work [20], [21], [22] it was found that about 20% of accidents (for a total of 39) occurred in the period from 2003 to January 2014 at biodiesel plants, was due to human error.

In the case of fuel ethanol facilities, for the period 1998-2014 only 7,5% of the accidents (over a total of 64) were caused by human error.

In Fig. 6 frequency-consequence curves are shown for biodiesel and ethanol industries.

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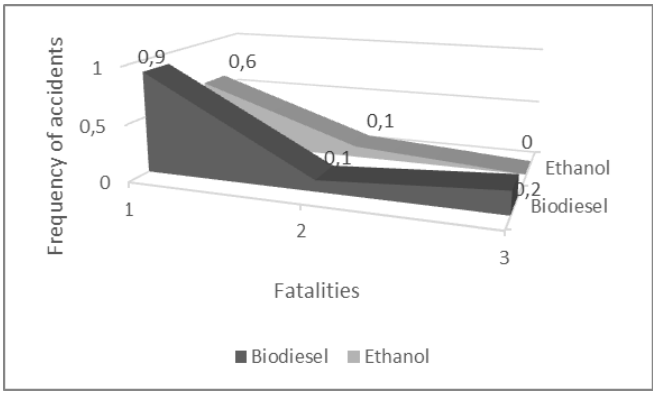

Fig. 6. Comparison of frequency-consequence curves for biodiesel and ethanol industries in the period 2003 to 2013.

Frequency-consequence curves are a common approach in complex engineering industries to express collective or societal risks in quantitative risk assessment.

This curves show the probability of accidents with varying degrees of consequence, such as fatalities.

VII. Comparative Assessment with Other Sectors

A comparison of accident risks associated with the energy sector, with special emphasis on the natural gas chain was made at Paul Scherrer Institut [7].

The results of this study provide a broader perspective on the gas-specific risk. Natural gas shows lowest expected fatality rates of all fossil energy chains.

In a new report a summary of severe accidents (with at least five immediate fatalities is provided. The time period considered is 1970 – 2008 [8] with accident statistic shown in Table II.

U. S. Administration [9], shows the quickly growth on biodiesel production during the last 10 years in main biodiesel producer countries and regions of the world. Increasing of production implies a major installed capacity [23], [24], [25], [26], [27], [28].

TABLE II
Summary of Accidents and Fatalities by Sector

Energy chain	Number of accidents	Number of fatalities
Coal	2526	41920
Oil	610	24254
Natural Gas	224	3181
LPG	150	5216
Hydro	11	4091
Nuclear	1	31
Biofuel	--	--
Biogas	2	18
Geothermal	1	21

According to a report of CADER [10] countries like Argentina, increased production capacity from about 568 thousand m3 of biodiesel in 2007 to more than 3,41 million m3 in 2012. The production growth [16], [17], [18], [19] has been accompanied by an increase of accident rates. According to Rivera and Mc Leod [11], [12] incidents have occurred due to the lack of expert operators and safe technologies.

Figures 7 and 8 show data from Table I, Fig. 1 and Fig. 2.

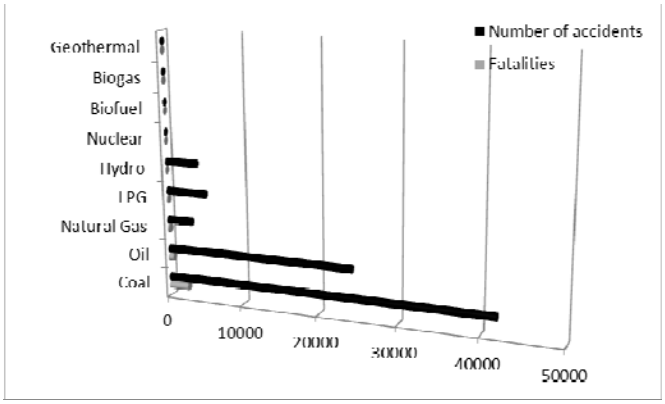

Fig. 7. Number of accidents and fatalities by sector.

Fig. 7 shows number of accidents and fatalities by geothermal, biogas, biofuel, nuclear, Hydro, LPG, natural gas, oil and Coal.

The number of accidents with fatalities in biofuel industry is distinctly minor than fossil chain. Coal has the higher number of fatalities joint to oil. Geothermal, biogas, biofuel and nuclear have numbers negligible face to other sectors.

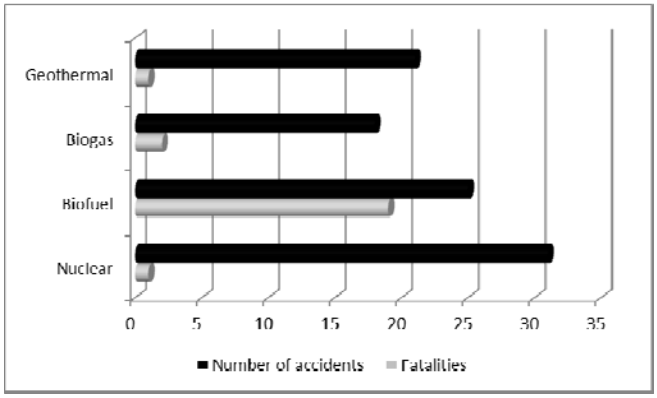

Fig. 8. Number of accidents and fatalities by sector.

Fig. 8 shows number of accidents and consequences (fatalities) for geothermal, biogas, biofuel and nuclear sectors.

Biofuel has the major number of accidents and more fatalities than biogas or geothermal sector. Geothermal has a lot of fatalities considering that had only one accident registered.

The relationship between fatalities vs. number of accidents is shown in Table III and Fig. 9.

TABLE II
Summary of Accidents and Fatalities by Sector

Sector	Fatalities/accidents
Coal	16,5954078
Oil	39,7606557
Natural Gas	14,2008929
LPG	34,7733333
Hydro	371,909091
Nuclear	31
Biofuel	1,31578947
Biogas	9
Geothermal	21

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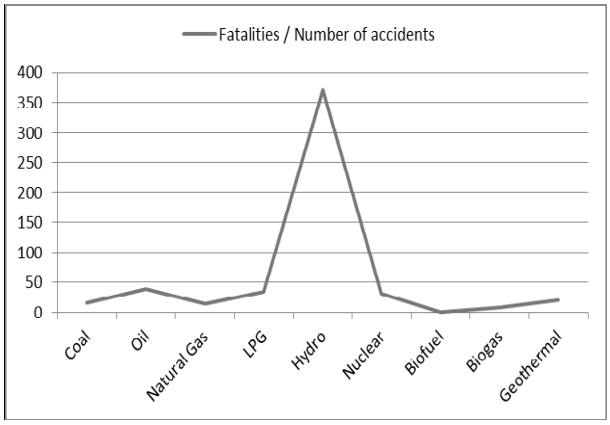

Fig. 9. Fatalities vs. number of accidents and by sector.

Fig. 9 shows clearly higher relationship between fatalities and number of accidents for Hydro sector and the minor for biofuel sector.

This is a preliminary study due to the lack of data from biofuel sector and data are obtained from different databases.

Within the area of process plant, risk analysis may be carried out for various reasons. The most common are [30]:

- to improve safety engineering
- to support the community planning process
- to provide a background for insurance decisions
- to support emergency planning.

VIII. Conclusions

In this work a preliminary comparative risk assessment approach was made.

The frequency of accidents with fatalities in biodiesel industry is 0.9 and 0.6 in ethanol industry. It is clear the need to improve safety in order to diminish the frequency and consequences detected in the occurrence of accidents.

Based on historical experience, maximum numbers of immediate fatalities were shown by different sectors. Oil and coal clearly exhibits maximum consequences. Between sectors of minor consequences, biofuel has the higher number of fatalities.

Due to it is a simple chemical process, safety frequently is omitted and it is important to note the lack of training in safety of the personnel.

The relationship between fatalities and number of accidents is the lowest (1.31).

Further work is necessary in order to improve this preliminary study.

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