



Database for accidents and incidents in the biodiesel industry



Romina D. Calvo Olivares*, Selva S. Rivera, Jorge E. Núñez Mc Leod

CEDIAC Institute, Eng. Faculty, Cuyo National University, Centro Universitario, CO M5502JMA, Ciudad, Mendoza, Argentina

ARTICLE INFO

Article history:

Received 30 December 2013

Received in revised form

27 March 2014

Accepted 29 March 2014

Keywords:

Database
Accidents
Incidents
Biodiesel plants
Risk analysis
Lessons learned

ABSTRACT

The present paper describes the development of an accident and incident database for the Biodiesel Industry for the period 2003–November 2013. The work performed 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 sequence, mitigation, causes, and human, environmental and material consequences occurring at biodiesel facilities during the last ten years. This database comes to fill a gap existing in this field. Availability of these data will allow applying risk analysis tools, having a management tool to check organization performance, generating lessons learned to avoid accident recurrence and identifying those accidents more likely to occur. Data statistical analysis shows that the frequency of accidents at biodiesel plants has an increasing tendency, being fires and explosions the main type of accidents that occurred. Immediate causes and consequences of the accidents have also been analyzed. Finally, some conclusions are drawn concerning the need of maintaining an update accidental and incidental database, and improving biodiesel plants safety based on information obtained.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Biodiesel has been defined by The American Society of Testing and Materials (ASTM) as monoalkyl esters of long chain fatty acids derived from a renewable lipid feedstock, such as vegetable oil or animal fat. It 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 biodiesel production. In Fig. 1 it can be seen the important growth of biodiesel production, in particular during the last decade. Data were obtained from the compilation done by Earth Policy Institute, World Biodiesel Production, 1991–2012, (2012).

Biodiesel is broadly produced by transesterification of triglycerides of virgin oils or renewable sources (refined/edible oils), using methanol and alkaline catalysts. Salzano, Di Serio, and Santacesaria (2010b) state that a minimum of 100,000 m³ size is required to consider the plant remunerative. This implies not only an increase of the equipment number but also of the amounts of hazardous and flammable materials being handled. Due to this fact, although biodiesel production processes are simple, operations

involve important risks if expert knowledge and safety technologies are not applied (Rivera & Mc Leod, 2012) and (Rivera & Mc Leod, 2008). It is also clear that not only a big installed capacity is associated to risks, performing unsafe procedures (e.g. welding methanol tanks) and/or the lack of knowledge about them (e.g. mixing glycerine and sulphuric acid in an improper ratio) can create favourable conditions for an accident.

While more relevant accidents at biodiesel facilities have been presented and some of them analyzed in literature (Marlair, Rotureau, Breulet, & Brohez, 2009; Rivera & Mc Leod, 2008; Salzano, Di Serio, & Santacesaria, 2010a; Salzano et al., 2010b; Salzano, Di Serio, & Santacesaria, 2010c) a record or a database that addresses all the accidents and incidents, with details of the facts, information about mitigation measures, probable causes and consequences has not been found yet.

For any industry, availability of data in an organized and systematic way allows:

- having background for risk assessment tools (Haastруп & Rømer, 1995);
- as a management tool, offering to an organization the opportunity to check its performance, learn from its mistakes, and improve its management systems and risk control (Nivolianitou, Konstandinidou, Kiranoudis, & Markatos, 2006);
- capturing valuable information that enables generate lessons learned to avoid accident recurrence (Kirchsteiger, Rushton, & Kawka, 1999);

* Corresponding author. Tel.: +54 261 4135000x2135.

E-mail addresses: rcalvo@cediac.uncu.edu.ar, rominacalvo@live.com.ar (R. D. Calvo Olivares), srivera@cediac.uncu.edu.ar (S.S. Rivera), jnmcLeod@cediac.uncu.edu.ar (J.E. Núñez Mc Leod).

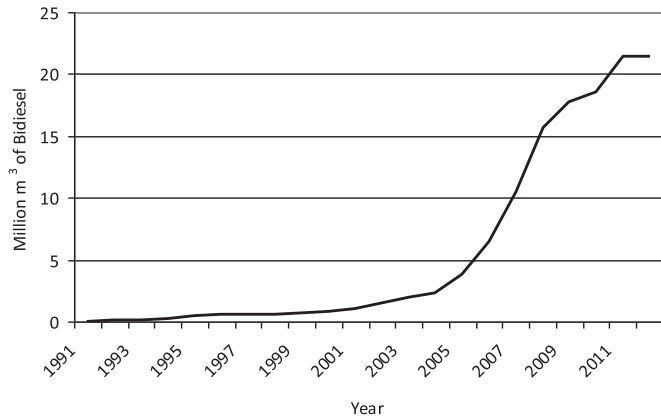


Fig. 1. Biodiesel world production, Million m³ of biodiesel vs year of production.

- identifying main risk sources and establishing what type of accidents are more likely to occur (Planas-Cuchi, Montiel, & Casal, 1997);
- reducing, as a result, the risk of incidents (probability of occurrence and/or the consequences of the incidents);
- finding and extracting information when necessary, in an easy and quickly manner;
- sharing objective information with other companies and third interested to avoid future occurrences (Sepeda, 2006).

This paper describes the procedure used to construct a database at international level to comprehend incidents and accidents in biodiesel plants for the period 2003 to November 2013. Occupational Safety and Health Administration defines *incident* as an unplanned, undesired event that adversely affects completion of a task while *accident* is defined as an undesired event that results in personal injury or property damage (OSHA, 1970). Only events inside biodiesel producer facilities were considered. Residential, road and transport accidents, and in plants under construction were not taken into account. The main purpose of collecting the available information is to gather all disseminated data on accidents, incidents and violations in the biofuel industry and create a reliable database which may be used for the aims described previously.

Section 2 of the paper presents a brief overview of the sources from which accident and incident information was extracted. Section 3 presents the methods used to develop the biodiesel accident database. Section 4 discusses the results obtained from the statistical analysis. Section 5 draws conclusions from the development and the use of the database. Finally, the Appendix presents a summary of collected data in a table.

2. Data sources

The procedure followed to build the biodiesel accident and incident database was similar to that found in papers such as Darbra and Casal (2004), Konstandinidou, Nivolianitou, Markatos, and Kiranoudis (2006), Rosman (2001) among others. It consisted in the collection, analysis and cross checking of the information to obtain a complete and unified register. The following sources were consulted:

- Occupational Safety and Health Administration (OSHA)

OSHA is a national public health agency created in the United States to assure safe and healthful conditions for working men and women by setting and enforcing standards and providing training,

outreach, education and compliance assistance. One of its roles is to conduct workplace inspections in response to workers' reports of hazards or accidental events. Then it elaborates technical reports called "OSHA regional News release" that are available on its webpage (OSHA, 1970).

- Industrial Fire World (IFW)

It is a source of information for industrial fire and emergency responders, and management worldwide. It has three interlinking platforms: IFW magazine provides data bi-monthly, the annual IFW Emergency Responder Conference that draws worldwide managers together giving them a time and a place to learn from each other and look at alternatives offered by new technology and strategy, and the internet platform (Fireworld, 1995) to search articles and incident logs published since 1995.

- Biodiesel Magazine

It is a source dedicated to the coverage of biodiesel news, events and information relevant to the global industry, with editorial focus on U.S. and international methyl ester manufacturing, trade, distribution and markets. It has two platforms: the bi-monthly trade journal and the internet webpage (Biodiesel Magazine) that allows searching articles related to biodiesel industrial safety.

- Biofuels Journal (BioFuels Journal, 2001) and Grainnet (Grainnet)

It is a family of websites that gathers news about the biofuel market and also provides useful information about industrial equipment. Biofuels Journal has a digital edition too.

- Steel Tank Institute (STI)

STI is a trade association representing fabricators of steel construction products and their suppliers. On its webpage (Steel Tank Institute), it is published a document called "Tank and Petroleum Use Mishaps" that contains data about industrial accidents.

- Environmental Protection Agency of United States (EPA, 1970)

It is a government agency concerned with the environment and its impact on human health. It formulates and enforces environmental regulations and helps companies to understand law requirements in order to maintain high environmental standards.

- Articles in academic journals
- Newspapers: national and local publications

3. Methods and data

3.1. Introduction

According to data published in Earth Policy Institute, World Biodiesel Production, 1991–2012 (2012), during the last decade biodiesel production has risen about twenty-seven times respect to that in year 2000. The increasing value given to biodiesel resides in the fact that it is obtained from renewable energy sources, it can be an alternative fuel in the face of declining oil reserves and it has known environmental advantages respect to fossil fuels. Although the process to obtain biodiesel is simple, it is associated to the storage, handling and transportation of flammable and hazardous chemical substances, and to the lack of experience, expert

knowledge and safety procedures (Rivera & McLeod, 2012; Rivera & McLeod, 2008).

In fact fires, explosions and releases have caused alarm among population, harm to people health in some cases, and financial losses, not only for the company where the incident took place, but also for neighbouring organizations and homes. Another aspect of these events is the negative image they give to biodiesel production and the possible feeling of rejection among population (Planas-Cuchi et al., 1997).

The above mentioned shows the potential risk and the consequences in case of a major accident at these facilities. Therefore, it is important to carry out a historical accident analysis and draw conclusions to improve the plant safety. So far, no complete accident database or register has been found that enables to have complete and unified information about accident type and rate of occurrence, causes and consequences (injured, deaths, material damages). Availability of these data will allow the implementation of risk analysis tools, the generation of lessons learned to avoid accident recurrence, the improvement of working procedures, the specialization of human resources, etc.

3.2. Data collection procedure

The database covers accidents and incidents in the biodiesel industry for the period from 2003 to November 2013 (last decade). Registered events comprise 55 facilities in the United States, 4 in Canada, 3 in Brazil, 2 in Argentina 1 in Australia, in Malaysia, China and Japan and a total of 10 plants in Europe: 2 in France, in the United Kingdom and Turkey, and 1 in Germany, in Spain, Belgium and Austria. This results in a total of 78 facilities in which accidents took place.

The complete biodiesel plant accidents list was prepared crossing information found in the different information sources mentioned in Section 2. This allowed obtaining in first place, the date, the location, the affected company's name in some cases, and a brief description of the event. Based on these data and using selective keywords, a generic search all over the web and a specific search in local newspapers were performed. Accident details were obtained by reading and extracting data of newspaper articles, institutional reports and papers.

Once the information was gathered, data were checked to avoid duplication or lack of register. It was found that:

- The same accident was registered in two different years. Available information corresponded to only one of them.
- In some cases, the date on which the event was registered does not correspond to that of occurrence but to that of the news article publication.
- For certain cases, a mention of the event is only available, and news articles that give details about it have not been found.

3.3. Nature of data collected

Data collected were based on about 90 documental sources between newspaper articles, papers and web pages. A total of 85 events were registered for a ten year period from 2003 to 2013 from the biodiesel industry. The number of accidents in biodiesel facilities per year is shown in Fig. 2.

Incident and accident reports include: mainly industrial accidents (spill or releases, fires and explosions), occupational incidents (slips, falls, burnings and cuttings) and meteorological phenomena affecting the facility.

The following figure (Fig. 3) shows the number of accidents by type according to the classification considered in 3.4.1 "Type of accident":

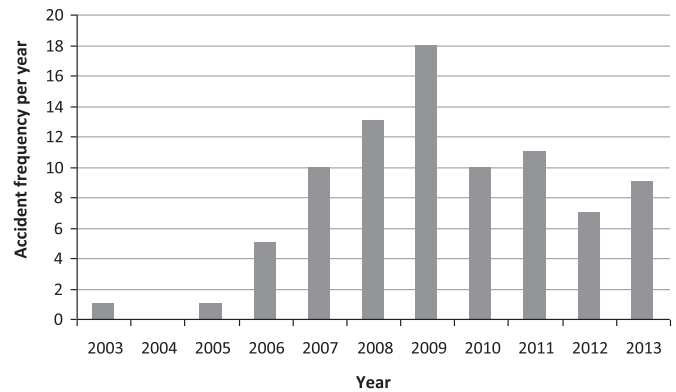


Fig. 2. Number of accidents in Biodiesel plants per year. Period 2003 to November 2013.

At first glance it can be determined that the major type of accidents that occur at biodiesel facilities are fires, in fact, of 85 analyzed events, in 60% (71) of the cases, a fire took place in the facility. It is important to note that an accident can belong to more than one classification due to an explosion may result in a fire or a release can lead a fire.

3.4. Data organization

Similar fields to the ones of existing world databases have been taken into account, adding some others considered of importance. It is a first approximation to a biofuel accident database and can be improved continuously in the future so as to include necessary details for specific purposes (e.g. developing a human reliability model). The database comprises four parts.

3.4.1. General part

This part includes all descriptive information about the event, comprising the following fields:

Item: the number of ordinal position (row) of any specific event in the database

Accident ID: this number facilitates the identification of the type of event when searching. It is a six digit alphanumeric code. The first digit identifies the type of biofuel industry: B (biodiesel) or E (Ethanol), the following two identify the country where the accident took place according to the system ISO 3166-1, the next one states its severity defined according to Table 1, and the last two digits identify the year of occurrence. If an accident can be identified by more than one category, the highest one will be

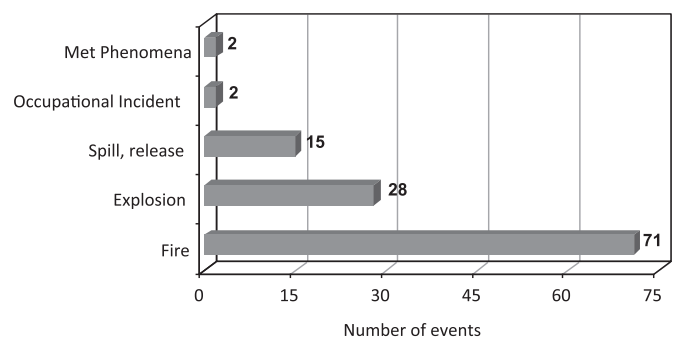


Fig. 3. Number of accidents by type in biodiesel facilities. Period 2003 to November 2013.

Table 1
Accident category according to consequences.

Accident category	Description
0	No consequences at all.
1	Minor structural damage and no injured people.
2	<10 Injured people and/or important structural damage
3	>10 injured people or environmental harm
4	Total loss of a building
5	Dead people

taken into account. In those cases in which there are no data about consequences the capital letter “N” replace the number.

For example, the ID BUS113 represents an accident that occurred in a Biodiesel plant of United States with minor structural damage in the year 2013; the ID BAU210 stands for an accident that took place at an Australian Biodiesel plant with less than 10 (2) injured people in the year 2010; the ID BUS307 represents an accident that occurred in a Biodiesel Plant of United States and caused environmental harm (river contamination) in the year 2007; and finally an ID such as BBR509 stands for an accident that occurred in a Biodiesel plant of Brazil and caused dead people in the year 2009.

Date: the date that the event took place.

Company: the company's name where the event occurred.

Capacity: the company's annual biodiesel production, expressed in thousand cubic metres/year.

Town: the city, village or municipality where the company is located.

State: the state or province where the company is located.

Country: the country where the company is located.

Background: previous information about incidents or accidents occurred at the company.

Events sequence: a brief description of the events leading to the incident or accident.

Mitigation: internal and external measures or actions put in place after the event occurrence in order to return the plant to normal condition.

Time of event: this field includes:

Day: the day of the week on which the event took place.

Hour: the hour in which the event took place.

Daily time: the daily time that the event occurred. This field is used in case of not having the exact hour but the mention of the daily time in which the event took place.

Status: the operational status of the facility when the event occurred (operation, maintenance or shut down)

Event area: the area inside the facility where the incident took place (storing, processing, loading and unloading, etc.)

Type of accident: in this field the type of accident is registered. The types of incidents and accidents are classified into: spill/release, occupational incident, explosion and fire. It is important to clarify that an accident can belong to more than one classification (e.g. an explosion may result in a fire or a release can lead a fire).

Outsourcing: this field is checked when outsourced personnel is involved in the event.

3.4.2. Causes

In this field, the cause of the incident or accident, as mentioned in the report or newspaper article is given. When no information of the cause is presented, this field is left empty. When the cause is being investigated, the field is filled with label ‘Under investigation’.

3.4.3. Consequences

The third part of the database involves the consequences of the event (if any). Information can be registered in the following fields:

1. Injuries

Number of injured: the number of injured people in the event.

Injury description: a brief mention of the type of injure or injuries people had as consequence of the event (e.g. burns, a broken arm, cuts, etc.).

2. Dead: the number of dead people is indicated in this field.

3. Assets

Damage description: a brief description of material damages to the facility.

Cost: the cost, expressed in dollars, of damages and/or recovery actions is introduced in this field.

4. Loss of production: the hours of lost production due to the incident or accident are indicated in this field.

5. Penalties: the cost of penalties (if any), expressed in dollars, that the company had to pay because of the incident or accident, is indicated in this field.

3.4.4. Additional information

The last field is used to register additional information on the event that was not included in any other field mentioned previously (e.g. violations), and could be important for future analysis.

4. Results and discussion

The analysis of the accident classification according to the ID number in Fig. 4 shows that the highest percentages of accidents belong to categories 2 (20%) and 4 (19%). Categories 1 and 5 represent each 14% of the total of adverse events. A 9% of the accidents deals with category 3 while only 4% did not have any consequences at all. In 20% there was not information about human and/or structural damages. These results are similar to that obtained analyzing consequences in Fig. 10. The difference lies in the fact that for accident ID if an event has more than one type of consequence, the most severe is considered to assign the category.

In Fig. 5 it is easily to observe that United States is the country where more accidents have occurred (59). Accidents with categories 1 and 3 have only taken place at United States. Accidents of category 1 have also occurred in France (1), Spain (1) and United Kingdom (1). Category 2 involves accidents that occurred in Argentina (1), Austria (1), Belgium (1), United Kingdom (1) in addition to United States (13). Category 4 includes accidents occurred in Argentina (1), Canada (2) and United Kingdom (1) plus United States (12). Fatalities have happened in Argentina (1), Brazil (3), Canada (1), China (1) and United States (5). For the rest of the cases, the category can not be determined due to the lack of data: Austria (1), Canada (1), France (2), Germany (1), Japan (1), Malaysia (1), Turkey (1) and United States (9).

The survey of 85 adverse events occurring at biodiesel plants shows, according to Fig. 2, that accident frequency grew up to 2009. In the following three years it has remained with a decreasing and increasing oscillatory behaviour. 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. Then, two more accidents were registered during the year but none of them with injured or dead people. This annual distribution of the accidents does not mean necessarily that accidents in biodiesel industry have increased during the analyzed period, but it is rather a demonstration that there is more availability of news (although much remains to do respect to report availability) and a

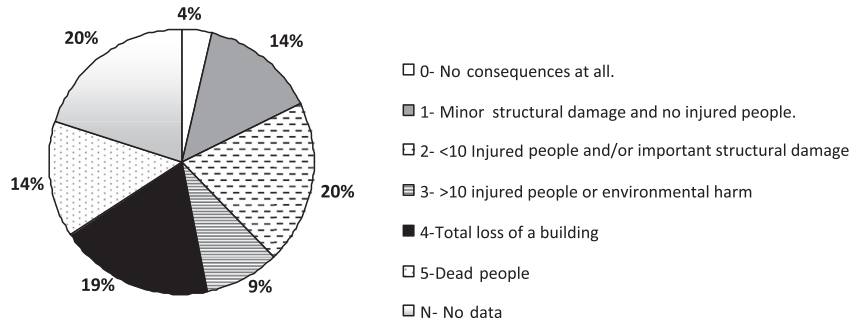


Fig. 4. Percentage of accidents according to ID category. Period 2003 to November 2013.

better access to information. The implementation of regulations related to occupational health, safety and environment are also factors that influenced. Finally, the diversification of raw materials and the continuous improving of biodiesel technology, both for mature processes (such as vegetable oil-based biodiesel) and for new processes, e.g. cellulosic biodiesel (EIA, 2012, p. 41), could influence the decrease of accidents. Even if the highest number of accidents occurred in 2009, according to Fig. 6 it was not the year with the higher number of dead. The major number of fatalities was in 2008 and the highest number of injured people was registered in 2012.

Fig. 7 is an $F-N$ curve, drawn in a logarithmic scale. It shows the accidents per year with N or more dead, or injured people. It was obtained considering only the accidents in which the number of

fatalities and injured people was known and different from zero. It can be observed that the frequency of accidents per year with 3 or more deaths is 2×10^{-1} . This agrees with the risk level of a system that has an operator and a supervisor. Accidents with 26 or more injured people has a frequency of 10^{-1} per year. This first analysis allows determining if the risks represented by the $F-N$ curve are tolerable or not. If we compare with any of the risk acceptance criterion established in Europe by legislation, risks levels at biodiesel plants are intolerable. Therefore, safety measures will be required to lower the $F-N$ curve. However, it should be noted that due to the lack of maturity of the industry and of risk based legislation, different results could not be expected.

According to Fig. 3, the main types of accidents are fires and explosions. This fact is due to the lack of knowledge about the chemical reactions involved and the improper handling of flammable substances used in biodiesel manufacturing such as

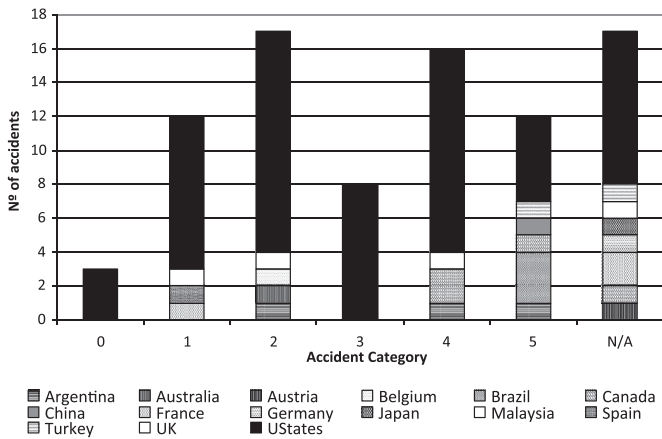


Fig. 5. Number of accidents per country vs accident category. Period 2003 to November 2013.

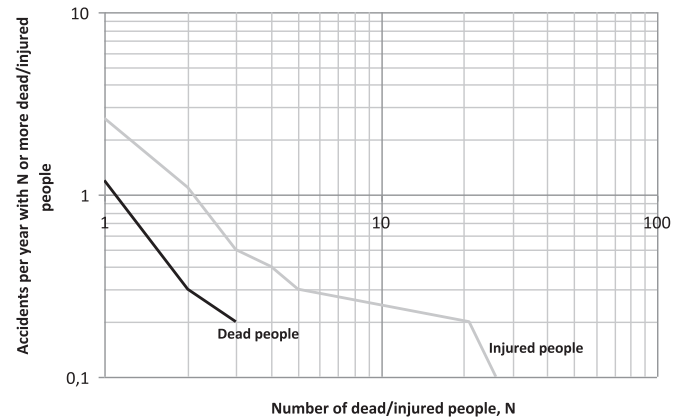


Fig. 7. Accidents per year with N or more dead or injures people in the biodiesel industry. Period 2003 to November 2013.

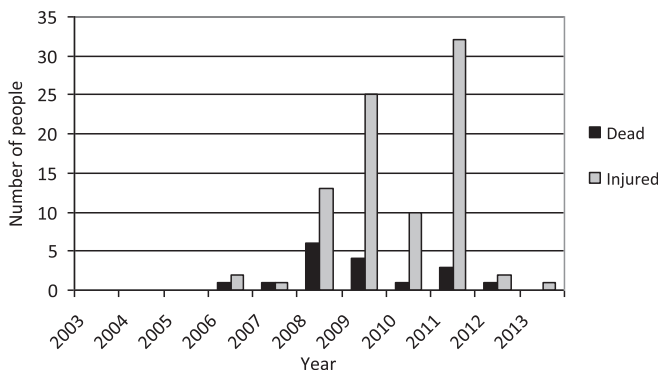


Fig. 6. Annual distribution of the number of injured and dead people in the biodiesel industry. Period 2003 to November 2013.

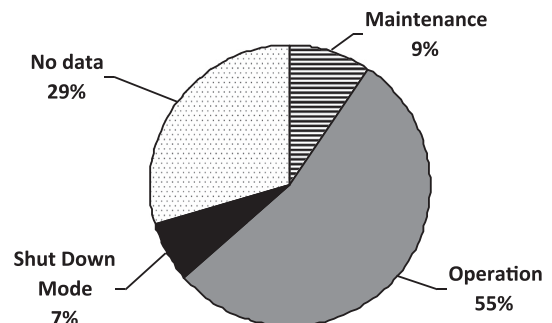


Fig. 8. Operational status during the occurrence of accidents at Biodiesel facilities. Period 2003 to November 2013.

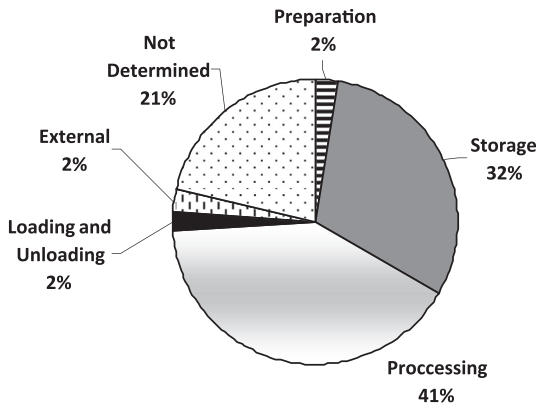


Fig. 9. Percentage of adverse events at Biodiesel plants per area of occurrence. Period 2003 to November 2013.

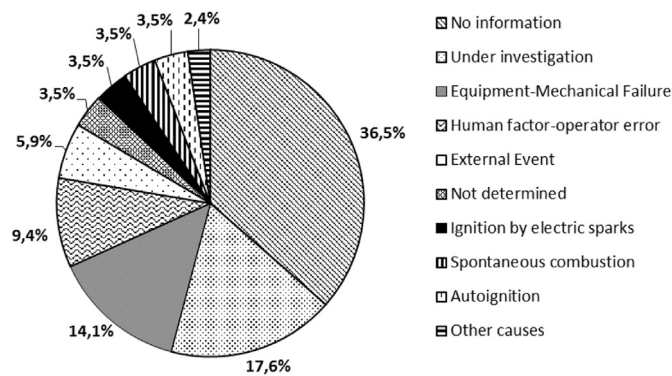


Fig. 10. Immediate causes of accidents and incidents in the biodiesel industry. Period 2003 to November 2013.

methanol (CH₄O), sodium or potassium hydroxide (NaOH, KOH) and sulfuric acid (H₂SO₄). Methanol has a very low flash point, this causes that its vapours can easily ignite if safety measures are not taken into account. NaOH or KOH are used as catalysts and mixed with methanol to obtain methoxides. If the water content of these substances is not the appropriate, they can potentially cause a fire due to the heat releasing when mixing with methanol. Pure sodium or potassium methoxide are not very stable and can ignite in contact with water or moist air. Finally, H₂SO₄ is not flammable but can cause a fire when it reacts with a combustible material (e.g. glycerin), or when it is in contact with an active metal and releases explosive hydrogen gas (e.g. when storing material is not properly).

Fig. 8 presents the operational status of the plant when the accident was reported. It shows that in more than half of the cases

(55%) the facility was under normal operation when the adverse event occurred. Critical phases like Maintenance and Shut down are represented by 9% and 7% respectively. Three of the accidents that occurred during maintenance phase involved contract workers who are not regular employees of the dangerous establishment and do not know the risks associated to the normal operation of the plant. In addition, they are usually poorly trained, do not follow job procedures or safety requirements, and there is a lack of communication and control from supervisors. In 29% of the cases data are not available so it is not possible to determine the status.

In Fig. 9 the areas where accidents took place are shown. As expected, the higher percentages of adverse events occurred in processing (42%) and storage areas (31%). This is due to the fact that handling and storing of flammable substances without properly procedures and safety measures can create favorable conditions to start an accident. Preparation, Loading and Unloading and External represent 2% each in the total number of accidents. Preparation includes the places where oil (used to obtain biodiesel) is prepared from grains. External involves other places in the site of the plant that are not associated with the previously mentioned areas. In 21% of the cases information was not enough to determine the area of the accident.

Fig.10 presents the immediate causes of accidents and incidents in the biodiesel industry for the period 2003–2013. It shows that in the 36.5% of the cases there is not information about event immediate causes and almost a 18% is under investigation, resulting in a lack of knowledge about the causes in more than half of the cases. Concerning the adverse events for which causes are known, the most frequent causes are Equipment-Mechanical failures (14.1%) and Human Factor –Operator Error (9.4%). For the last one, the most common root causes are procedural and supervision failures. It should be noted that if equipment- mechanical failures could be analyzed in depth, the contribution of the human factor would be probably higher since planning and execution of maintenance tasks depend on operators.

In Fig. 11, the immediate consequences of the accidents and incidents reported in the Biodiesel Industry for the period 2003–Nov 2013 are presented. As for the type of accidents, there is an overlap among the consequence categories since certain accidents can involve more than one type of consequence (e.g. fatalities and partial material loss). There were only three accidents where no consequences were reported. During the 10 year period twelve accidents involve fatalities and 17 people lost their lives while 26 accidents caused a total of 86 injured people. Material loss was registered in 52 cases from which 17 involved total destruction of the plant or at least, of one of the buildings. Accidents that produced harm to the environment were registered in seven cases while eight cases were found to cause community disruption such as evacuation of surrounding areas of the accident or shutting down of two line trains in one of the cases.

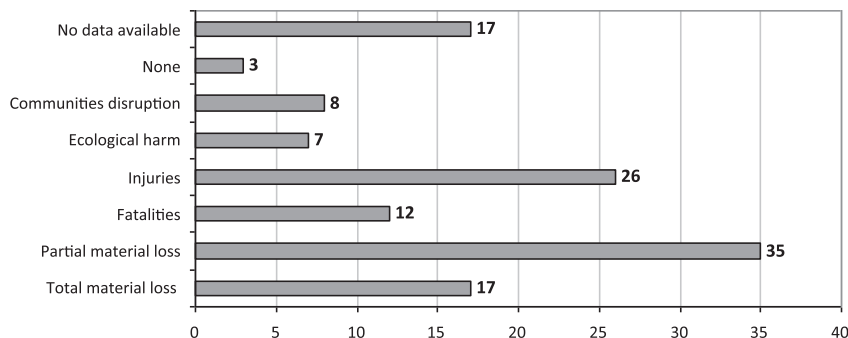


Fig. 11. Consequences of accidents and incidents in the biodiesel industry. Period 2003 to November 2013.

5. Conclusions

A database to include all accidents and incidents of the biodiesel industry has been developed for several purposes.

The creation of a database that gathers information about accidents and incidents that have occurred during the last decade (2003–2013) comes to fill a gap existing in the knowledge of biodiesel production. So far there was no a complete data record about accidents and incidents occurred at biodiesel facilities that could be analyzed in order to avoid accident recurrence. This is a first attempt although much remains to work and develop.

Exchanging of recorded information between industries in the biodiesel area and the distribution of the database to other stakeholders is a further target. This will make easy to companies to learn from others' experience and to know about the most probable causes of accident, identifying all factors that usually participate in an accident sequence. Based on this data, the company can detect main risks and safety problems associated with operations at the facility and make decisions to change or improve working procedures, plant and process design or working environment. Additionally, considering only the information provided by a company, the type of hazards and failures will be limited. Databases built through cooperation and integrated effort from facilities of all the biodiesel industry can provide further information. A clear example of this is OREDA Project (Offshore RELiability Data) which is a comprehensive databank with reliability and maintenance data for exploration and production equipment from different geographic areas, installations, equipment types and operating conditions and it is run by a group of oil companies (OREDA, 1981).

Maintaining of the database will require a responsible management by each company that will imply a complete register of the information each time an accidental or incidental event occurs. Data gaps make it difficult to the analyst to carry out a deep analysis of the adverse event and the consequent proposal for preventive actions. Gathered data exhibit this problem: information about causes, consequences or even about the event itself is not available in all cases.

The study presented here reveals that there is an immediate need to improve safety measures, working procedures and to train personnel at biodiesel plants, in order to diminish the frequency and consequences detected in the occurrence of accidents. While it is clear that process safety can be achieved by common sense and enforcement of established codes and standards, considerable expertise is needed to comprehensively mitigate biodiesel manufacturing risks. This expertise can be acquired through lessons learned from past accidents and incidents. However, this task will be difficult if the company do not maintain a register of accidental and incidental data. Because of that it is crucial to develop and maintain a database which gathers information about accidents and incidents.

Acknowledgements

This work was supported in part by CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas) and SeCTyP (Secretaría de Ciencia, Tecnología y Posgrado) of Cuyo National University, Argentina.

Appendix

In the following table a comprehensive register of biodiesel plant accidents and incidents is shown. Data have been organized into a compact form. Some data such as those corresponding to "Accident ID", "Mitigation", "Outsourcing" or "Additional Information" fields are not considered.

Table 1
Accident and Incident register. Period 2003–November 2013.

Item	Date daily time	Company capacity [thousand m ³ /year] location	Events sequence	Status ^a event Area ^b	Type of accident ^c	Causes	Consequences [N ^e injured (injury description)/N ^e dead/damage/cost]	Source	Report availability
1	11/16/2013 Morning	REV Biodiesel, (37.85), Gilbert, AZ, USA.	A fork lift operator punctured a 1254 m ³ barrel of methyl alcohol, the volatile mixture of the methyl alcohol and nearby sulphuric acid ignited a fire, it was put out by the plant's sprinkler system.	OP RMS	F S	Ignition of a volatile chemical mixture.	0/0	(The Arizona Republic) (ABC 15 News)	
2	07/30/2013 Morning	Green Energy Products LLC, Sedgwick, KS, USA.	Some cylinders and other vessels exploded at the plant, a fire took place, flames were about 92–122 m in the air and sent black smoke at one point and caused the metal building's roof to collapse, at least a dozen people were inside the facility when the fire started. A fire started in the plant.	OP PRO	E F	Under investigation	0/0/Production plant destroyed.	(The Wichita Eagle) (KWCH 12)	
3	05/24/2013 Afternoon	Eagle Biodiesel, Inc. (100), Jackson, AL, USA.	Some biodiesel ensconced filter media spontaneously combusted in the tray beneath the filter press, a fire was created in the wash-dry building of the plant, it burned for several hours, the fire must have raged in isolation most of	ND NDT	F	No information	0/0/Unknown damage	(Waff 48 news)	
4	05/21/2013 Night	Piedmont Biofuels, Pittsboro, NC, USA.		ND PRO	F	Spontaneous combustion	0/0/Lot of smoke damage and partial electricity in the wash-dry facility, an overhead crane damaged.	(Piedmont Biofuels)	

(continued on next page)

Table 1 (continued)

Item	Date daily time	Company capacity [thousand m ³ /year] location	Events sequence	Status ^a event Area ^b	Type of accident ^c	Causes	Consequences [N° injured (injury description)/N° dead/damage/cost]	Source	Report availability
5	05/03/2013	U.S. Biofuels Inc.(45.4), Rome, GA, USA.	the night, melting electrical conduit and PVC water lines. Personnel started operations, there was a problem near a pump, something failed, it caused a leak and a fire.	OP PRO	F S	Mechanical malfunction	1 (minor burn)/0/some electrical wiring and maybe some plastic tubing have to be replaced	(Rome News-Tribune)	
6	04/29/2013 Morning	Pacific Biodiesel Technologies LLC (11.4), Honolulu, HI, USA.	The plant was at normal operation, a malfunctioning fuel system inside one of the boilers allowed a fuel build-up to occur, it ignited and caused the fire.	OP PRO	F	Fuel build-up inside of a boiler due to a malfunctioning system	0/0	(Hawaii News Now)	
7	04/07/2013 Morning	Midwest Biodiesel Products LLC (45.4), South Roxana, IL, USA.	Two employees were moving chemical containers, they noticed a flash fire in a pipe.	OP PRO	F	No information	0/0/Minor damage to the building	(News 4 St. Louis)	
8	02/20/2013	Diester Industrie, Grand-Couronne, Alta Normandy, France.	A fire started in a tank storage area, which stores biodiesel residual dust.	ND BPS	F	No information	No data available	(Terre & Finance)	
9	02/08/2013 Morning	Blue Sun St. Joe Refining (113.6), St Joseph, MO, USA.	The plant was at normal operation, possibly the biodiesel level in the 760 m ³ fuel storage tank dropped below the regulated level, the roof of the tank exploded.	OP BIS	E	No information	0/0/Enough damage to the tank to put it out of service	(KQTV2)	
10	10/01/2012 Afternoon	Speedway International Inc. (18.9), St. Boniface, Manitoba, Canada.	Plant was at normal operation but work in the plant stopped momentarily because raw material to purify biodiesel had not come, fire ignited in the empty plant, it set off alarms that called some workers and fire-fighters, the explosion caused a huge fireball that could be seen for kilometres.	OP BIS	E F	Exothermal reaction of canola oil inside a filter press or spontaneous combustion of oily rags	0/0/Destruction of the biodiesel plant, 15-million dollars of damage	(ChrisD.ca)	
11	09/23/2012 Morning	Petrotec AG (210.1), Südlohn-Oeding, Borken, Germany.	A fire broke out in a side production line of its biodiesel production process.	OP PRO	F	No information	No data available	(Ad Hoc News)	
12	08/24/2012 Night	Golden Leaf Energy LLC (8.3), Harvey, LA, USA.	The plant was in normal operation, 2 men mixed 114 L of sulphuric acid and 570 L of methanol, it produced an explosion, the back of the building went up flames and spread to 2 cars nearby.	OP PRO	E F	Under investigation	1 (minor injuries)/1/2 vehicles destroyed, warehouse damaged	(WWL-TV Channel 4) (The Times-Picayune)	
13	06/15/2012 Morning	Natural Biodiesel Plant LLC (18.9), Hayti, MO, USA.	The plant was in normal operation, approximately 15 buckets of resin were poured into a processing tower, an explosion broke out, a worker was injured.	OP PRO	E F	Under investigation	1 (minor burns)	(WPSD Local 6)	
14	05/15/2012 Afternoon	Soy Energy LLC (113.6), Mason, IA, USA.	A methanol tank exploded, it caused a small fire.	OP RMS	E F	Under investigation	0/0/Minimal damaged limited to a tank	(Globe Gazette)	
15	03/11/2012 Night	Promethean Biofuels Co-op Corp. (7.9), Temecula, CA, USA.	The facility operates on a six-day schedule, it shut down early on Saturday, the rags used to clean in the biodiesel process were put in a drum not properly contained, they caught fire, it damage a nearby filter press.	OP PRO	F	Improperly disposal of oily rags	0/0/Filter press damaged, a small amount of water, oil and fire suppressant chemicals runoff and reached the nearby creek	(The Press-Enterprise)	
16	02/11/2012 Night	Ottawa, Ontario, Canada.	A 18 m by 24 m shop that was used to make biodiesel caught fire.	OP PRO	F	Under investigation	Collapse of the building, a trailer and a vehicle destroyed/375,000 damage	(CTV News)	
17	11/14/2011 Evening	Archer Daniels Midland Company's, Deerfield, MO, USA.	Fire started in a grain hopper on the 1st floor of the preparation building, another blaze discovered in ductwork	OP PRO	F	No information	0(although 2 employees with asthma taken to hospital as a precaution)/0	(KY3) (KSN Local News)	

18	09/08/2011 Night	Cooperativa Agrícola y Forestal Gral. Güemes Ltda., Gral Güemes, Sgto. del Estero, Argentina	on the 3rd floor, employees found smoke in a tank outside the building. A fire started in the manufacturing area of the plant, it extended toward the three storehouses that are adjacent to each other, behind administration offices and to few meters from the gin.	ND PRO	F	Under investigation	Total destruction of the processing building and the seed and machinery stores, lost of 400L of cotton oil/ 773562 (seeds for sowing and fodder)	(Diario Norte)
19	08/12/2011 Morning	Carboneras, Almería, Spain.	Bleaching earth (used to filter biodiesel) was stored in a 4000 L silo, the silo was open to the air, the substance remained in contact with air more time than indicated, it autoignited causing a fire.	ND RMS	F	Bleaching earth autoignited	Damaged silo	(Teleprensa)
20	07/30/2011 Afternoon	Tennessee Bioenergy Inc. (18.9), Summitville, TN, USA.	The plant was in normal operation, a spark out of a motor of methanol was produced, it ignited the methanol and a fire was produced, about 114 m ³ of methanol were consumed by the fire.	OP RMS	F	Sparks ignited methanol	1 (slight burns on his arm)/0/Plant destroyed	(4HD) (News channel 5)
21	05/29/2011 Night	Viesel Fuel LLC (3.6), Stuart, FL, USA.	The business was shut down for the long Memorial Day weekend, nobody was occupying the building, a blaze occurred.	SD PRO	F	Structural fire	0/0/Building seriously burned	(The Palm Beach Post)
22	05/14/2011 Evening	American Biodiesel Energy Inc. and North American Powder Coatings (18.9), Erie, PA, USA.	Explosions took place in Powder-coating business, flames shot at least 100 feet from the roof and thick, black, acrid smoke billowed from the building, fire spread eastward to the back of the building and engulfed that side, it destroyed more of the northern wall and most of the roof.	ND OUT	E F	Under investigation	26 (variety of respiratory problems, 3 with minor injuries, one of the 3 treated with chemical burns)/0/ Powder-coating business destroyed, minor damage to the biodiesel plant, firemen's equipment damaged	(Erie Times-News)
23	04/19/2011 Night	AG Energy-Viluco S.A. (227.1), Frías, Sgto. del Estero, Argentina.	Three workers were doing the clean-up in a silo, the closing valve of the silo was opened, operators were sucked up by the silo, one of them came out but the others became trapped, they died from asphyxia.	MA GRA	O	Valve of the silo was left opened	1(nervous breakdown)/2	(Geonavitas)
24	04/11/2011 Morning	Oleoplan S.A. (99.9), Veranópolis, Rio Grande do Sul, Brazil.	The plant was in a scheduled maintenance, a worker was welding a 14 thousand-litres tank, the tank was used for the treatment of water used in biodiesel production, it contained oil and fat, the tank exploded.	MA PRO	E F	No information	2 (both with cuts on face and body)/1	(Pioneiro)
25	03/26/2011 Morning.	Plantation Inn, Dunnellon, FL, USA.	The plant was in normal operation, biodiesel was being processed, a fire took place.	OP BIS	F	No information	0/0/38–76 L of finished product, storage building and shed destroyed	(Chronicle online)
26	03/04/2011 Morning	Clear Sky Biofuels Inc., Clearfield, UT, USA.	The equipment of the plant was off, they were processing vegetable oil to remove impurities, an air tank used in the process overheated, it caused a vapour explosion in the plant, the fire quickly spread to The Cartel (Clear Sky's next-door neighbour).	OP PRO	E F	A mechanical problem with the air tank's temperature	2 (flash burns on the backs of the legs of one of them, hit head the other)/0/2 buildings destroyed/ \$600,000 to \$700,000	(The Salt Lake Tribune) (KSL)
27	02/01/2011 Afternoon	Northern Biodiesel Inc. (75.7), Ontario, NY, USA.	A fire broke out inside the plant.	OP PRO	F	Two pump motors overheated	0/0/Ceiling damaged	(YNN)
28	12/27/2010 Afternoon	Southern Indiana BioFuels, Newburg, IN, USA.	The plant was at normal operation, an oil boiler used to heat the barn where they store fuels started the blaze.	OP BIS	F	Under investigation	0/0/Minor damage to the building, an oil storage tank damaged.	(Local 7 CW) (The Evansville Courier & Press)
29	12/11/2010 Afternoon	Soy Energy (1.9), Tyrone Twp., PA, USA.	A fire broke out in the biodiesel warehouse.	OP BIS	F	Spontaneous combustion	1 (no description)/0/ destroyed building	

(continued on next page)

Table 1 (continued)

Item	Date daily time	Company capacity [thousand m ³ /year] location	Events sequence	Status ^a event Area ^b	Type of accident ^c	Causes	Consequences [N° injured (injury description)/N° dead/damage/cost]	Source	Report availability
30	10/11/2010 Evening	U.S. Biofuels Inc.(45.4), Rome, GA, USA.	There was probably a discharge from the plant, a landowner said a black substance in the water of a near creek (Ward Creek).	ND NDT	S	No information	At least one mile of a near creek affected	(The Gettysburg Times) (Rome News-Tribune)	
31	10/06/2010 Afternoon	Fina Bio Fuels, Melbourne, Victoria, Australia.	The plant was at maintenance routine, a man was welding a large cylinder-type vat estimated to be 10–20 m tall, it contained a mixture of glycerol and methanol, there was an explosion, the cylinder blown 130 m away the facility, crews heard it 500m down the road.	MA BPS	E	Under investigation	2 (one with 50% of his body seriously burned and induced coma, the other knocked off by explosion)/0/a cylinder and 3 cars damaged.	(Herald Sun) (Whittlesea Leader)	
32	09/27/2010	Carter Energy Ltd., Wujin, Changzhou, Jiangsu, China.	An explosion took place.	ND NDT	E	No information	1 (no description)/1	(John Astad, 2011)	
33	07/30/2010 Afternoon	Advanced Refining Concepts, Sparks, NV, USA.	A gas tank of 475- litres containing biodiesel fuel exploded into a worker's face and upper body, the tank leaked bio-diesel fuel outside the business.	OP PRO	E F	Under investigation	3 (1 hospitalized with 3rd degree burns on his face and upper body and the other 2 treated for smoke inhalation)/0/Leak of biodiesel outside the plant.	(Channel 2 News)	
34	07/17/2010 Night	AG Energy-Viluco SA (227.1), Frías, Stgo. del Estero, Argentina.	A fire started in the pre- treatment area of the plant.	OP PRO	F	Under investigation	2(one with 1st-grade burns and the other with asphyxia by carbon monoxide inhalation)	(El diario24.com)	
35	07/15/2010 Afternoon	Innovations Fuels (151.4), Newark, NJ, USA.	The plant was in normal operation, a worker was connecting hoses to a tanker truck filled with methanol, a 1.52- litres sulphuric acid container behind him leaked, possibly there was an ignition source and it burned, 380 –760 L of acid spilled and flooded the structure.	OP RMS	F S	Under investigation	1 (hospitalized with 3rd-degree burns to 18% of his body)/0/380 to 760 L of acid spilled and flooded the structure, a vapour cloud was created as a result of the acid explosion	(New Jersey online)	
36	06/18/2010 Night	Robin Fuels, Keighley, UK.	The one-story building (known as Middleton works) was used to manufacture and sell biodiesel, fire broke out for the 2nd time, it destroyed the building.	ND BIS	F	It is believed the fire was intentional	Destroyed building	(Keighley News)	
37	06/01/2010 Midnight	Robin Fuels, Keighley, UK.	The one-story building (known as Middleton works) was used to manufacture and sell biodiesel, fire broke out, it wrecked the inside.	ND BIS	F	It is believed the fire was intentional	Biodiesel plant damaged	(TheTelegraph & Argus)	
38	12/02/2009 Afternoon	Imperium Grays Harbor (378.5), Hoquiam, WA, USA.	The plant was at normal operation, operators were mixing sulphuric acid with glycerine, they introduced 21 times more acid into the neutralization mix than the process was designed for, it created an exothermic reaction, the 38 m ³ tank containing heated glycerine exploded, a large chunk of the tank was blown at least 100 feet away and crashed through a chain-link fence, it sent aluminium and insulation across the plant and into nearby properties,	OP PRO	E S	Overpressure in a glycerine processing tank due to the improper mixture ratio with sulphuric acid	0/0/Mixing tank destroyed, a biodiesel tank damaged and a sulphuric acid tank ruptured, a spill of about 1.9 m ³ L of sulphuric acid in the basin around the tank, damaged pipes, a chain link fence broken by a large chunk of the tank	(The Seattle Times) (The Daily World)	

			heated glycerine mixed with cold air created a large vapour plume, the explosion also damaged 2 other tanks, the one containing sulphuric acid ruptured and spilled an unknown amount of acid.					
39	11/24/2009 Night	Minnesota Soy Bean Processors (113.6), Brewster, MN, USA.	The plant had just started-up after a brief scheduled maintenance shut down, it is thought that smoldering debris were undetected, air systems were activated, a fire was detected in an air system in the soybean preparation area of the plant.	OP MIA	F	Smoldering debris flamed up when air systems were activated	0/0/No damage to the equipment	(Agweek)
40	10/13/2009 Afternoon	Xenerga Biodiesel, Savannah, GA, USA.	The plant was at normal operation, a reactor containing finished biodiesel product exploded.	OP PRO	E F	Under investigation	1 (a broken leg)/0/Building severely damaged	(WSAV 3)
41	09/24/2009 Afternoon	New Eden Energy LLC, St. Cloud, FL, USA.	The plant was at normal operation, it stored 15.2 m ³ of biodiesel, 11.4 m ³ of methanol, 1.14 m ³ of sodium methane and 0.21 m ³ of sulphuric acid, the sulphuric acid tank ruptured, acid found an ignition source, it exploded causing a fire, it quickly spread and was fueled by thousands of gallons of chemicals.	OP RMS	E F	Rupture of a sulphuric acid tank or a malfunctioning thermostat	0/0/The biodiesel facility, a separate office and several vehicles destroyed	(WFTV Channel 9)
42	09/03/2009	Louis Dreyfus Agricultural Industries LLC (302.8), Claypool, IN, USA.	An equipment fire broke out	ND NDT	F	No information	No data available	(Industrial Fire World, 2009b)
43	08/19/2009 Afternoon	Cooperbio – Cooperativa de Biocombustível (124.9), Cuiabá, Mato Grosso, Brazil.	The plant was at normal operation, an operator plant shut down a catalytic machine in a tank, the 4000 L- biodiesel tank would have a mixture of methanol, ammonium hydroxide and sodium, a short circuit was produced, it ignites flammable vapours causing a explosion, a biodiesel leakage took place, it contaminated the land.	OP PRO	E F S	Possibly there was a short circuit	2 (one with burn mouth and possibly affected by inhalation of toxic fumes and hot air)/1/Destroyed equipment, building damaged	(Folha de S. Paulo)
44	07/17/2009 Morning	Columbus Foods Co. (11.4), Chicago, IL, USA.	The company was at normal operation, the neutralization phase of glycerine was being carried out in a tank of about 10 feet in diameter and 20 feet high, a worker mixed glycerine with an oversupply of sulphuric acid, an exothermic reaction was produced, it caused the tank explosion and started a fire, a plume of smoke smelling strongly of chemicals and sulphur lingered in the air for several minutes, the explosion sent bricks and debris flying hundreds of feet in the air.	OP PRO	E F	Overpressure in a glycerine processing tank due to the improper mixture ratio with sulphuric acid	21 (one received scratches, other splashed with chemicals, the rest suffered from skin irritation)/0/ Plant's roof and walls collapsed, the lid of the tank left a crater in a close school parking lot and a heavy pipe hit the school, other buildings damaged	(Chi Town Daily News) (Chicago Tribune)
45	07/16/2009	Duzco, Turkey.	An explosion rocked a biodiesel plant	ND NDT	E	No information	No data available	(Industrial Fire World, 2009a)
46	07/04/2009 Morning	Gen-X Energy Group Inc. (18.9), Burbank, WA, USA.	The plant was not operating at the time, a blaze started outside in a portable toilet on the northwest corner of the facility, it spread to the roof of the biodiesel plant, about 114 m ³ of vegetable oil spilled.	SD OUT	F S	It is believed the fire was intentional	Destroyed plant	(NBC Right Now)
47	06/30/2009	Energy Alternative Solutions Inc. (3.8), Gonzales, CA, USA.		ND RMS	F	No information	No data available	(Fireworld, 1995)

(continued on next page)

Table 1 (continued)

Item	Date daily time	Company capacity [thousand m ³ /year] location	Events sequence	Status ^a event Area ^b	Type of accident ^c	Causes	Consequences [N° injured (injury description)/N° dead/damage/cost]	Source	Report availability
48	06/15/2009 Afternoon	Midwest Biorenewables, Toledo, OH, USA.	A dumpster fire at a biodiesel plant threatened nearby drums of sulphuric acid. The plant had been producing diesel fuel from soybean oil for about a month, a vacuum-control valve that should have regulated a vacuum-refining vessel failed to work, biodiesel inside became hot, it ignited upon contact with air, the vessel implode causing a fire.	OP PRO	F	Failure of a safety valve	0/0/One production line destroyed	(The Blade)	
49	06/04/2009 Morning	Ecobiodiesel, Burnley, Lancashire, UK.	The plant used to heat the cooking oil to thin it out before using it to obtain biodiesel, the heater on one of the vats was left on overnight, the thermostat failed, the vat overheated, it exploded and caught fire, flames quickly spread to the building's structure, plumes of smoke could be seen as about 4 km.	OP PRO	E F	A thermostat on one vat failed	A vat destroyed	(Lancashire Telegraph)	
50	05/23/2009 Evening	Minnesota Soy Bean Processors (113.6), Brewster, MN, USA.	Six employees were working at the plant, they saw smoke in the soybean oil and biodiesel loading area.	OP RMS	F	No information	0/0/A soybean oil and biodiesel load out equipment, a biodiesel storage tank's insulation and a soybean oil storage tank damaged	(The Daily Globe)	
51	03/23/2009 Afternoon	Binatural, Formosa, Goiás, Brazil.	Three operators were doing maintenance working in a local of the plant, they were welding a glycerine tank, it exploded, workers fell of 12 m-high, explosion caused cracks in the tank, a glycerine leak was produced, the fire spread through glycerine leaked.	MA BPS	E F S	No information	0/3/a destroyed tank	(Folha de S. Paulo)	
52	03/21/2009	Athens Biodiesel (151.4), Athens, AL, USA.	Fire at a biodiesel plant	ND NDT	F	No information	1(critical condition)	(Fireworld, 1995)	
53	02/25/2009	Athens Biodiesel (151.4), Athens, AL, USA.	Water from tanks washed, it caused a fish kill.	ND NDT	S	No information	A fish kill in a nearby stream	(Fireworld, 1995)	
54	02/19/2009 Night	Hardin Fuels Inc. (3.8), Kountze, TX, USA.	A fire took place in the processing unit.	OP PRO	F	Electrical problem in one of the walls or in a refrigerator in the building	0/0/Equipment and structure of the processing unit destroyed, one storage tank damaged/About 300,000 dollars in equipment and structural damage	(12 News)	
55	02/07/2009 Afternoon	GreenHunter BioFuels LLC (397.4), Houston, TX, USA.	The plant was at normal operation, a mechanical seal on a circulation pump associated with a process heating unit failed, excessive heat was produced, a fire started.	OP PRO	F	A mechanical seal failure on a circulation pump	0/0/Minimal damage/About 50,000 dollars in repairing costs.	(Biodiesel Magazine)	
56	11/22/2008	Hatay, Antakya, Turkey.	A lightning stroke on the biodiesel facility, a fire erupted, the building collapsed.	ND NDT	M	A lightning strike	5 (no description)/3/A collapsed building	(Hürriyet)	
57	11/05/2008	Midland County, TX, USA.	Several oil tanks caught fire	ND BIS	F	No information	No data available	(Fireworld, 1995)	
58	09/30/2008 Night	Nova Biosource Fuels Inc. (37.9), Clinton, IA, USA.	The facility was idled for routine maintenance, there was no biodiesel	MA PRO	F		1 (minor steam burns)/0/ Damaged equipment	(Quad-City Times)	

			inventory on site, workers made the ventilation process, methanol vapours build up in the primary biodiesel recovery column, vapours ignited, a small fire broke out.			A build up and ignition of methanol vapours in the column		
59	09/17/2008	Gadsten Fleet Management Facilities, Gadsden, AL, USA.	The facility was at normal operation, the reactor was used to obtain biodiesel, an operator put grease and oil, a heating element of the reactor failed, the oil hit the element and ignited, the burst plate did not get off to relieve pressure, pressure built up inside the reactor causing the fumes ignited, the burst plate blow off, it produced a hole in the roof of about 1 ft in diameter.	OP PRO	F	A faulty heating element on biodiesel equipment	0/0/A hole in the roof of the building process, equipment damaged	(The Gadsden Times)
60	09/13/2008	GreenHunter BioFuels LLC (397.4), Houston, TX, USA.	The facility had been completely shut down in the 48 h prior to the hurricane strike, all personnel had been evacuated, a hurricane stroke, the plant flooded, a canola oil tank spilled less than 190 L into the environment.	SD NDT	M S	A hurricane	0/0/Minimal damage to process equipment, raw material lost, structural losses: offices, smaller reagent tanks, intermediate tanks and interconnecting piping and pumps, some small and intermediate tank foundations, 2 bulk storage tanks damaged, destruction of many electrical panels, power outage, lack of utility services/About 22.4 million dollars in total damages 1 (respiratory problems)/0/	(Waste & Recycling News)
61	08/24/2008 Midnight	All American Biodiesel Inc., York, ND, USA.	The biodiesel plant had not been in operation for 72 h, only a refrigerated air dryer and a low pressure compressor were working that night, the fire started in an area that held electrical equipment, a plastic container of acid melted from the fire but the acid remained in place because of the design of the building, it was neutralized, most of the insulation of 2 biodiesel steel tanks burned off, 1200 pounds of plastic plates melted in a filter press used to removed ions from the finished biodiesel.	SD BPS	F	Not determined	One of the buildings destroyed and all the equipment inside	(Biodiesel Magazine)
62	08/15/2008 Morning	Biofuel of Tennessee LLC (37.9), Davis, TN, USA.	The plant has been in shut down mode for the last four months, there was an explosion.	SD NDT	E	No information	0/0/Processing building completely destroyed, lost of the existing stocks of methanol and some acid substances used	(News channel 5)
63	07/01/2008	Winchester, KY, USA.	A small fire broke out.	ND NDT	F	No information	No data available	(Industrial Fire World, 2008)
64	06/28/2008	Serembain, Malaysia.	A small fire broke out.	ND NDT	F	No information	No data available	(Fireworld, 1995)
65	05/18/2008 Afternoon	Greenlight Biofuels Princess Anne LLC (18.9), Princess Anne, MD, USA.	Two operators were contracted to do piping work between facility tanks, they purged a gas line, one of them started to weld while a methane line was being added to the plant, they hit the gas line, an explosion occurred.	MA BIS	E	Under investigation	1(no data)/1/A section of the roof buckled and a side of the building damaged	(WESM 91.3 FM)

(continued on next page)

Table 1 (continued)

Item	Date daily time	Company capacity [thousand m ³ /year] location	Events sequence	Status ^a event Area ^b	Type of accident ^c	Causes	Consequences [N° injured (injury description)/N° dead/damage/cost]	Source	Report availability
66	04/15/2008 Morning	Western Biodiesel Inc. (18.9), Calgary, Alberta, Canada.	A worker from the plant and a sub-contractor determined creating a new fitting for a malfunctioning sensor on three 9-m biodiesel settling tanks, they were drained, only one of them was purged using compressed air, the sub-contractor welded the 1st tank, then he started welding the 2nd, fumes and methanol inside ignited by heating, it caused an explosion, it tore off a chunk of the roof and blew a hole in the building.	MA BIS	E F	Ignition of fumes in the tank	0/1/Tank roof buckled and what appeared to be insulation was fluttering in the wind	(Canada.com)	
67	04/07/2008 Afternoon	Northwest Missouri Biofuels LLC (56.8), St. Joseph, MO, USA.	Rail cars at the plant usually carried biodiesel or ingredients for the fuel such as soybean oil or animal fat, one worker fell in an empty tanker car, other climbed into the car to help.	OP LAU	O	No information	1(no description)/1	(News- Press 3 Now)	*
68	01/03/2008 Afternoon	American AG Fuels (26.5), Defiance, OH, USA.	The plant was at normal operation, a manhole cover on a 38-m ³ storage tank filled with glycerine was left open, the tank was heated to keep the glycerine from gelling, it started to release fumes, an employee smelled them, it opened an overhead garage door operated by an electric motor to air out the building, sparks of the motor ignited the fumes, it caused one large explosion and then smaller second explosion.	OP BPS	E F	Glycerine vapours ignited by sparks	4 (one with 3rd-degree burns on his hand and 1st- and 2nd-degree burns on his upper body, other suffered cracked ribs, the last one hospitalized for cuts and pressure wounds, a police officer suffered from smoke inhalation)/0/ Power went out in the city, structural damage in the processing building, loading and unloading facility totally destroyed, damage into a neighbour building	(WNWO News)	
69	09/08/2007	Guelph, Ontario, Canada.	A large pile of wood chips caught fire, smouldering for weeks.	ND NDT	F	No information	No data available	(Fireworld, 1995)	
70	09/01/2007 Night	New Leaf Biofuel LLC (7.6), San Diego, CA, USA.	A fire started in the plant.	ND NDT	F	No information	1(in comma with 4th degree burns over 90% of his body)/0/Existing damage	(U-T San Diego)	
71	08/25/2007	Foothills Bio-Energies LLC (18.9), Lenoir, NC, USA.	The plant had been shut down for 2 days for cleanup and a tour, a fire started in 2 outside storage tanks in the containment area around the feedstock tank farm, it destroyed the tanks, some of the liquids in the holding tanks spilled out.	SD RMS	F S	Not determined	Minor damage inside the plant, feedstock tanks destroyed, some of the liquids spilled into a stream	(WFMY News 2)	
72	08/23/2007	E-Biofuels LLC (56.8), Middletown, IN, USA.	Construction materials in a trash bin caught fire	ND NDT	F	No information	No data available	(Fireworld, 1995)	
73	08/21/2007	Farmers and Truckers Biodiesel (18.9), Augusta, GA, USA.	The facility was idled for maintenance, the 2.1 m ³ mixing tank where operators were going to do the job had previously held sodium methalate, it was purged, then it was checked and 2 leak detection systems found no combustible gases, an operator had	MA PRO	E F	Superheating of the air inside the tank by welding or ignition of sodium methalate vapours left inside	0/1/1.9 m ³ of oil products found in ditches and runoff (Violations to the Georgia Environmental Acts)	(News 12)	

74	07/27/2007 Morning	General Biodiesel Seattle LLC (18.9), Seattle, WA, USA.	been welding a flow meter on a pipe going into a the tank for several hours, the tank exploded. The facility was in normal operation, an employee pumped a processing-chemical mixture of vegetable oil, biodiesel, sodium hydroxide, methanol and glycerine from a large tank (22.8 m ³) to a small portable tank (1.14 m ³), the transfer was left unattended, the small tank overflowed, the mixture ran across a driveway into a small inlet along the Duwamish River, an oil sheen and diesel odour were reported at Ecology, about 2.36 m ³ of the mixture reached the waterway and about 87 L were recovered.	OP PRO	S	A transfer of a chemical mixture was unattended	River contamination (with a mixture of biodiesel, methanol, sodium hydroxide and other processing chemicals). No reports of fouled birds or fish killed.	(Department of Ecology)
75	07/25/2007	Better Biodiesel Inc. (11.4), Spanish Fork, UT, USA.	The facility was at normal operation, it was using animal fat as a feedstock to optimize the company's process design, a mechanical malfunction in a transfer line within the reactor section was produced, it caused a fire.	OP PRO	F	Mechanical malfunction of a transfer line in the reactor section	A damaged reactor	(WorldNet Daily)
76	07/14/2007	Agri Biofuels, Dayton, TX, USA.	A fire resulted from a methanol spill	OP RMS	F S	No information	No data available	(Fireworld, 1995)
77	02/11/2007	FutureFuel Chemical Co. (223.3), Batesville, AR, USA.	A fire broke out.	ND NDT	F	No information	No data available	(The Batesville Daily Guard)
78	01/27/2007	Oleon NV (113.6), Ertvelde, Evergem, Belgium.	The facility was at normal operation, there was a leak in the distillation column of the fatty acid plant, the fat at a high temperature came in contact with oxygen, it caused an explosion.	OP PRO	E F	No information	0/0/Part of the fatty acid plant damaged	(Oleon)
79	08/12/2006	Austria	An explosion and fire in a tank were reported	ND NDT	E F	No information	No data available	(Fireworld, 1995)
80	07/17/2006	Diester Industrie, Venette, France.	A process safety device at the biodiesel production unit failed, it caused a chimney fire.	OP PRO	F	No information	Limited damages	(Marlair et al., 2009)
81	07/07/2006	Blue Sky Biodiesel LLC (45.4), New Plymouth, ID, USA.	Personnel at Blue Sky Biodiesel had been retrofitting a formal fruit-packing plant over the past few months and were just beginning full-scale production, an employee was working on top of an about 6.7 m -high steel tank using an oxyacetylene torch to install a vent, the tank apparently contained some methanol and glycerine, the torch ignited methanol vapours, it caused an explosion that touched off another smaller explosion and a fire that quickly engulfed the entire building, fire generated a thick black smoke.	OP RMS	E F	The torch used to weld a tank ignited methanol vapours inside	2 (one of them suffered from 2nd-degree burns and smoke inhalation)/1/The tank room and boiler rooms of the plant destroyed	(Casper Star -Tribune) *
82	06/23/2006 Afternoon	Sunbreak Biofuels, Canby, OR, USA.	The facility was a start up biodiesel company, biofuel was stored in plastic tanks, a fire started in the electric wiring of the barn, a biodiesel tank melted, several gallons of biodiesel spilled from the heat damaged tank, fire spread to the rest of the tanks.	OP BIS	F S	Under investigation	A barn and processing and storage equipment were total lost, several gallons of biodiesel spilled from a heat damaged tank	(The Salem News)

(continued on next page)

Table 1 (continued)

Item	Date daily time	Company capacity [thousand m ³ /year] location	Events sequence	Status ^a event Area ^b	Type of accident ^c	Causes	Consequences [N° injured (injury description)/N° dead/damage/cost]	Source	Report availability
83	02/17/2006 Afternoon	American Biofuels (18.9), Bakersfield, CA, USA.	The plant was in full production mode, two operators were carrying methanol in containers of 1 tn., a container fell from a forklift, the container did not break but methanol splashed out, a container aluminum bar dragged along and hit the concrete, sparks were generated, they ignited the methanol spilled, the fire spread into the plant, smoke could be seen from miles around.	OP LAU	F S	Static electricity: sparks ignited methanol spilled	0/0/The 929 square-meter facility and equipment destroyed, minor damage to the exterior of a railcar where corn oil was stored/At least 2 million dollars in equipment damage	(The Bakersfield Californian)	
84	08/7/2005	Nagoya, Chubu, Japan.	A facility worker simply placed a work rag in a cardboard box, apparently the rag autoignited, the rag and box were consumed by the fire.	OP PRO	F	Spontaneous ignition of the rags	No data available	(Biodiesel Magazine)	
85	08/04/2003	Grand-Couronne, Alta Normandy, France.	Fire started in a cooling tower.	ND NDT	F	No information	No data available	(Marlair et al., 2009)	

^a Status: MA = Maintenance, OP = Operation, SD = Shut Down Mode, ND = Not determined.

^b Event Area: BIS = Biodiesel Storage, BPS = By-Products Storage, BBS = By-Products and Biodiesel Storage, RMS = Raw Material Storage, PRO = Processing, GRA = Grain Area, MIA = Milling Area, LAU = Loading and Unloading, OUT = Outside plant building, NDT = Not determined.

^c Type of accident: F = Fire, E = Explosion, S = Spill, release, O = Occupational Incident, M = Meteorological phenomena.

References

- 12 News (KBMT-DT2) Website. Port Arthur, TX, USA. Retrieved May 9, 2013, from www.kbmt12.com.
- 4HD (WSMV-TV channel 4) Newspaper Website. Nashville, TN, USA. Retrieved May 7, 2013, from www.wsmv.com.
- ABC 15 News (KNXV-TV) Website. Phoenix, AZ, USA. Retrieved November 20, 2013, from www.abc15.com.
- Ad Hoc News Website. Berlin, Germany. Retrieved May 6, 2013, from www.ad-hoc-news.de.
- Agweek Website. Retrieved May 8, 2013, from www.agweek.com.
- American Society of Testing and Materials (ASTM) Website. Retrieved May 6, 2013, from <http://astm.org>.
- Biodiesel Magazine Website. Retrieved March 16, 2013, from www.biodieselmagazine.com.
- BioFuels Journal (2001, 2013) Website. Retrieved March 16, 2013, from <http://www.biofuelsjournal.com>.
- Canada.com Newspaper Website, Toronto, Canada. Retrieved May 10, 2013, from www.canada.com.
- Casper Star-Tribune Newspaper Website. Casper, WY, USA. Retrieved May 16, 2013, from <http://trib.com/>.
- Channel 2 News (KTVN-TV) Website. Reno, NV, USA. Retrieved May 8, 2013, from www.ktvn.com.
- Chi Town Daily News Website. Chicago, IL, USA. Retrieved May 9, 2013, from www.chitowndailynews.org.
- Chicago Tribune Website. Chicago, IL, USA. Retrieved May 9, 2013, from www.chicagotribune.com.
- ChrisD.ca, Winnipeg News and Media Website. Winnipeg, Manitoba, Canada. Retrieved May 6, 2013, from www.chrisd.ca.
- Chronicle online Website. Citrus County, FL, USA. Retrieved May 8, 2013, from www.chronicleonline.com.
- CTV News Website. Toronto, Ontario, Canada. Retrieved May 7, 2013, from <http://ottawa.ctvnews.ca>.
- Darbra, R.-M., & Casal, J. (2004). Historical analysis of accidents in seaports. *Safety Science*, 42(2), 85–98. [http://dx.doi.org/10.1016/S0925-7535\(03\)00002-X](http://dx.doi.org/10.1016/S0925-7535(03)00002-X).
- Department of Ecology Website. WA, USA. Retrieved May 16, 2013, from www.ecy.wa.gov.
- Diario Norte Website. Resistencia, Chaco, Argentina. Retrieved May 31, 2013, from www.diariornorte.com.
- Earth Policy Institute, World Biodiesel Production, 1991–2012. (2012). Retrieved July 26, 2013, from www.earth-policy.org.
- U.S. Energy Information Administration. (2012). *Biofuels Issues and Trends. Independent Statistics & Analysis*. Washington, DC 20585. Retrieved February 11, 2014, from www.eia.gov.
- El diario24.com Website. Santiago del Estero, Argentina. Retrieved May 31, 2013, from www.eldiario24.com.
- EPA. (1970). *Environmental Protection Agency*. WA, USA. Retrieved March 16, 2013, from www.epa.gov.
- Erie Times – News Website. Erie, PA, USA. Retrieved May 7, 2013, from www.goerie.com.
- Fireworld (1995). Website. Retrieved April 16, 2013, from www.fireworld.com.
- Folha de S. Paulo Newspaper Website. Sao Paulo, Brazil. Retrieved May 9, 2013, from www.folha.uol.com.br.
- Geonavitas Newspaper Website, Bauness, Bs. As., Argentina. Retrieved May 7, 2013, from www.geonavitas.com.ar.
- Globe Gazette Newspaper Website. Mason City, IA, USA. Retrieved May 7, 2013, from <http://globegazette.com>.
- Grainnet Website. Retrieved March 16, 2013, from www.grainnet.com.
- Haastrup, P., & Rømer, H. (1995). An analysis of the database coverage of industrial accidents involving hazardous materials in Europe. *Journal of Loss Prevention in the Process Industries*, 8(2), 79–86.
- Hawaii News Now Newspaper Website. Honolulu, HI, USA. Retrieved May 17, 2013, from www.hawaiinewsnow.com.
- Herald Sun Newspaper Website. Melbourne, Australia. Retrieved May 8, 2013, from www.heraldsun.com.au.
- Hürriyet Newspaper Website. Turkey. Retrieved May 9, 2013, from www.hurriyet.com.tr.
- Industrial Fire World (2008, October). No.5, 23, 23.
- Industrial Fire World (2009a, October). No.5, 24, 12.
- Industrial Fire World (2009b, December). No.6, 24, 9.
- John Astad. (2011). *Biodiesel accidents Map*. Combustible Dust Policy Institute. Retrieved May 8, 2013, from www.combustibledust.com.
- Keighley News Newspaper Website. Keighley, West Yorkshire, England. Retrieved May 8, 2013, from www.keighleynews.co.uk.
- Kirchsteiger, C., Rushton, A., & Kawka, N. (1999). A text retrieval method for the European Commission's MARS database: selecting human error related accidents. *Safety Science*, 32(2), 71–91.
- Konstandinidou, M., Nivolianitou, Z., Markatos, N., & Kiranoudis, C. (2006). Statistical analysis of incidents reported in the Greek Petrochemical Industry for the period 1997–2003. *Journal of Hazardous Materials*, 135(1–3), 1–9. <http://dx.doi.org/10.1016/j.jhazmat.2005.10.059>.
- KQTV2 (abc) Website. St. Joseph, MO, USA. Retrieved May 6, 2013, from <http://stjoechannel.com>.
- KSL Website. Salt Lake City, UT, USA. Retrieved May 8, 2013, from www.ksl.com.

- KSN Local News (KSNF, channel 6) Website. Joplin, MO, USA. Retrieved May 7, 2013, from <http://fourstateshomepage.com>.
- KWCH 12 Website. Wichita, KS, USA. Retrieved November 20, 2013, from www.kwch.com.
- KY3 (KYTV channel 3) Website. Springfield, MO, USA. Retrieved May 7, 2013, from <http://articles.ky3.com>.
- Lancashire Telegraph Newspaper Website. East Lancashire, England. Retrieved May 9, 2013, from www.lancashiretelegraph.co.uk.
- Local 7 CW (WTVW, Local 7) Website. Evansville, IN, USA. Retrieved May 8, 2013, from <http://tristatehomepage.com>.
- Marlair, G., Rotureau, P., Breulet, H., & Brohez, S. (2009). Booming development of biofuels for transport: Is fire safety of concern? *Fire and Materials*, 33(1), 1–19. <http://dx.doi.org/10.1002/fam.976>.
- NBC Jersey Now Website. WA, USA. Retrieved May 9, 2013, from www.kndu.com.
- New Jersey online Newspaper Website. NJ, USA. Retrieved May 8, 2013, from www.nj.com.
- News 12 (WRDW-TV) Website. Augusta, GA, USA. Retrieved May 16, 2013, from www.wrdw.com.
- News 4 St. Louis (KMOV) Website. St. Louis, MI, USA. Retrieved May 17, 2013, from www.kmov.com.
- News-Press 3 Now Website. St. Joseph, MO, USA. Retrieved May 15, 2013, from www.newspressnow.com.
- Newschannel 5 (WTVF-TV) Website. Nashville, TN, USA. Retrieved May 7, 2013, from www.newschannel5.com.
- Nivolianitou, Z., Konstandinidou, M., Kiranoudis, C., & Markatos, N. (2006). Development of a database for accidents and incidents in the Greek petrochemical industry. *Journal of Loss Prevention in the Process Industries*, 19(6), 630–638. <http://dx.doi.org/10.1016/j.jlp.2006.03.004>.
- Oleon Company Website. Retrieved May 16, 2013, from www.oleon.com.
- OREDA (1981). Website. Retrieved November 19, 2013, from www.oreda.com.
- OSHA (1970). Website. WA, USA. Retrieved April 16, 2013, from <http://www.osha.gov>.
- Piedmont Biofuels Website. Pittsboro, NC, USA. Retrieved June 4, 2013, from www.biofuels.coop.
- Pioneiro Newspaper Website. Caxias do Sul, Rio Grande do Sul, Brasil. Retrieved May 8, 2013, from <http://pioneiro.clicrbs.com.br/rs>.
- Planas-Cuchi, E., Montiel, H., & Casal, J. (1997). A survey of the origin, type and consequences of fire accidents in process plants and in the transportation of hazardous materials. *Process Safety and Environmental Protection*, 75(1), 3–8.
- Quad-City Times Newspaper Website. Davenport, IA, USA. Retrieved May 10, 2013, from <http://qctimes.com>.
- Rivera, S. S., & McLeod, J. E. N. (2008). Human error in biofuel plants accidents. In *Proceedings of the World Congress on Engineering* (Vol. 2). Retrieved from http://iaeng.org/publication/WCE2008/WCE2008_pp1237-1242.pdf.
- Rivera, S. S., & McLeod, J. E. N. (2012). Recommendations generated about human reliability analysis on biodiesel plants. In *Proceedings of the World Congress on Engineering* (Vol. 1). Retrieved from <http://www.doaj.org/doi?func=fulltext&aid=1098065>.
- Rome News-Tribune Newspaper Website. Rome, GA, USA. Retrieved May 17, 2013, from <http://romenews-tribune.com>.
- Rosman, D. L. (2001). The Western Australian Road Injury Database (1987–1996): ten years of linked police, hospital and death records of road crashes and injuries. *Accident Analysis & Prevention*, 33(1), 81–88.
- Salzano, E., Di Serio, M., & Santacesaria, E. (2010a). Emergency safety issues for biodiesel production plant. In *4th International Conference on Safety & Environment in Process Industry: CIPSAP4* (Vol. 19). Florence, Italy: Simberto Senni Buratti.
- Salzano, E., Di Serio, M., & Santacesaria, E. (2010b). Emerging risks in the biodiesel production by transesterification of virgin and renewable oils. *Energy & Fuels*, 24(11), 6103–6109. <http://dx.doi.org/10.1021/ef101229b>.
- Salzano, E., Di Serio, M., & Santacesaria, E. (2010c). State-of-art and historical analysis for the safety of biodiesel production by trans-esterification of virgin and renewable oils. In *7th European Congress of Chemical Engineering, ECCE-7. Prague, Czech Republic*.
- Sepeda, A. L. (2006). Lessons learned from process incident databases and the process safety incident database (PSID) approach sponsored by the Center for Chemical Process Safety. *Journal of Hazardous Materials*, 130(1–2), 9–14. <http://dx.doi.org/10.1016/j.jhazmat.2005.07.061>.
- Steel Tank Institute Website. Retrieved March 16, 2013, from www.steeltank.com.
- Teleprensa Newspaper Website. Almería, Spain. Retrieved May 7, 2013, from www.teleprensa.es.
- Terre & Finance Newspaper Website. France. Retrieved May 6, 2013, from www.terrefinance.fr.
- The Arizona Republic Newspaper Website. Phoenix, AZ, USA. Retrieved November 20, 2013, from www.azcentral.com.
- The Bakersfield Californian Newspaper Website. Bakersfield, CA, USA. Retrieved May 16, 2013, from www.bakersfieldcalifornian.com.
- The Batesville Daily Guard Newspaper Website. Batesville, AR, USA. Retrieved May 16, 2013, from <http://guardonline.com>.
- The Blade Newspaper Website. Toledo, OH, USA. Retrieved May 9, 2013, from www.toledoblade.com.
- The Daily Globe Newspaper Website. MI, USA. Retrieved May 9, 2013, from www.yourdailyglobe.com.
- The Daily World Newspaper Website. Aberdeen, WA, USA. Retrieved May 8, 2013, from <http://tdw.thedailyworld.com>.
- The Evansville Courier & Press Newspaper Website. Evansville, IN, USA. Retrieved May 8, 2013, from www.courierpress.com.
- The Gadsden Times. (n.d.). Website. AL, USA. Retrieved May 10, 2013, from www.gadsdentimes.com.
- The Gettysburg Times Newspaper Website. Gettysburg, PA, USA. Retrieved May 8, 2013, from www.gettysburgtimes.com.
- The Palm Beach Post Newspaper Website. West Palm Beach, FL, USA. Retrieved May 7, 2013, from www.palmbeachpost.com.
- The Press-Enterprise Newspaper Website. Inland Empire, CA, USA. Retrieved May 7, 2013, from www.pe.com.
- The Salem News Newspaper Website. Beverly, MA, USA. Retrieved May 16, 2013, from www.salem-news.com.
- The Salt Lake Tribune Newspaper Website. Salt Lake City, UT, USA. Retrieved May 8, 2013, from www.sltrib.com.
- The Seattle Times Newspaper Website. Seattle, WA, USA. Retrieved May 8, 2013, from <http://seattletimes.com>.
- The Times-Picayune Newspaper Website. New Orleans, LA, USA. Retrieved May 7, 2013, from www.nola.com.
- The Wichita Eagle Newspaper Website. Wichita, KS, USA. Retrieved November 20, 2013, from www.kansas.com.
- Telegraph & Argus Newspaper Website. Hall Ings, Bradford, United Kingdom. Retrieved May 8, 2013, from www.thetelegraphandargus.co.uk.
- U-T San Diego Newspaper Website. San Diego, CA, USA. Retrieved May 15, 2013, from www.utsandiego.com.
- Waff 48 news Website. Huntsville, AL, USA. Retrieved June 3, 2013, from www.waff.com.
- Waste & Recycling News Website. Detroit, MI, USA. Retrieved November 6, 2013, from www.wasterecyclingnews.com.
- WESM 91.3 FM Website. University of Maryland Eastern, Princess Ann, MD, USA. Retrieved May 10, 2013, from <http://wesm913.org/news>.
- WFMY News 2 (WFMY-TV) Website. Greensboro, NC, USA. Retrieved May 16, 2013, from www.digtriad.com.
- WFTV Channel 9 (abc) Website. Orlando, FL, USA. Retrieved May 9, 2013, from www.wftv.com.
- Whittlesea Leader Newspaper Website. Melbourne, Australia. Retrieved May 8, 2013, from <http://whittlesea-leader.whereilive.com.au>.
- WNWO News (WNWO-TV) Website. Toledo, OH, USA. Retrieved May 15, 2013, from www.northwestohio.com.
- WorldNetDaily Newspaper Website. WA, USA. Retrieved May 16, 2013, from www.wnd.com.
- WPSD Local 6 (WPSD-TV) Website. Cape Girardeau, MO, USA. Retrieved May 7, 2013, from www.wpsdlocal6.com.
- WSAV 3 (WSAV-TV) Website. Savannah, GA, USA. Retrieved May 9, 2013, from www.wsav.com.
- WWL-TV Channel 4 Website. New Orleans, LA, USA. Retrieved May 7, 2013, from www.wwl.com.
- YNN, Your News Now Website. Rochester, NY, USA. Retrieved May 8, 2013, from <http://rochester.ynn.com>.