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Human Error in Biofuel Plants Accidents

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Abstract— **Actually, biofuel is an industry in expansion. There is a lot of plants installed in a lot of countries. These plants like other chemical plants can have accidents with fatal consequences. Being an industrial facility, risks and dangers exist related to transport, storage and use of great amount of toxic chemical substances and flammable and highly polluting vegetal oil tanks.**

In this work a gathering of biofuel plants accidents are evaluated. Some recommendations and conclusions are presented. Human reliability considerations are the main issue found.

Index Terms—**Biofuel plants, accidents, human reliability.**

I. Introduction

Biofuel is an abbreviation of bioorganic fuel. It is an alternative considered to replace petroleum gas. They can be made from sugar, starch, vegetable oil or animal fats using conventional technology and they are referred as first generation fuels.

The most common first generation fuels are vegetable oil, biodiesel, bioalcohol, biogas and solid biofuel as wood, charcoal or died manure.

Second generation of biofuel is made from a variety of non food crops.

Third generation biofuel are made from algae.

The use of biofuel generates a smaller contamination environmental. It is a viable alternative to the exhaustion of fossil energy.

The importance and increasing valuation is related with the following issues:

1) environmental, due to the reduction of carbon emission;
2) economical, by the perspective of exhaustion of fossil fuels;
3) social, by the generation of opportunities for agriculture and
4) strategic, in relation to the promotion of transition energies to foment the renewable energy sources, adapted to the present technologies, avoiding great modifications in engines that use fossil fuels.

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A. The cycle of biofuel

Biofuel are desirable because the plants from which it is created store carbon as they grow (see Figure 1).

Therefore the carbon released during its uses is offset, it will be reabsorbed by the new plants being grown for fuel.

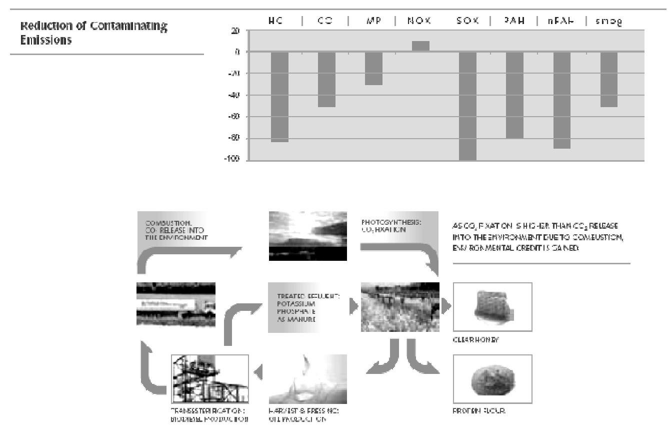

Figure 1. Cycle of biofuel

On a first stage, the cycle of biofuel is concerned with the cycles of bioethanol, biodiesel and biomass of vegetable origin. In all of these cases, the cycle starts when a given species is planted to get the raw material which will be the basis of the biofuel. Both willows and poplars are suitable for producing the pellets, fire logs and chips that will be eventually used as fuels in household or industrial furnaces, while the organic matter remaining is compostable. Topinambur is a promising resource, because the sugars derived from this crop can be fermented to obtain bioethanol, while the organic matter remaining is compostable. Sunflower, jatropha and rapeseed yield an oil which can be transesterified (transesterification is the reaction of an oil plus alcohol occurring in the presence of a catalyst) into biodiesel. Rapeseed represents a special case because it is a heavy nectar plant from which honeybees produce a light colored honey that is highly priced in international markets; its seeds can be pressed for oil and yield a by-product in the form of a high-protein flour which is used as animal feed. Finally, all biofuel are burnt. As combustion takes place, biofuel release CO2 into the environment (carbon dioxide) at a rate that is lower than the amount fixed during the cultivating process. Then, where does the rate difference go to? This difference is incorporated into the land as compostable material or as manure, and constitutes the so called environmental credit. The full cycles of biofuel represent a series of additional benefits, which go beyond the environmental credit gained. In this respect, the use of biodiesel helps to eliminate the production of sulphur composites, to substantially reduce particulate and aromatic material emissions and consequently to improve the quality of air. By selecting and/or developing the right technology, the products which would be regarded as waste can acquire added value [1]-[2].

B. *Impact analysis*

Life cycle analysis [3] is a systematic evaluation of the environmental and resource consequences of a particular product, process, or activity from "cradle to grave." By analyzing entire life cycle of a product from extraction and processing of raw materials through final use and disposal, LCA can assess systematically the impact of each component process. There are three separate but interrelated components in a LCA: an inventory analysis, an impact analysis, and an improvement analysis.

The life cycle inventory uses inventory, monitoring and material flow data to quantify energy and raw materials requirements, air emissions, waterborne effluents, solid waste, and other environmental releases incurred throughout the life cycle of a product, process, or activity.

The results from a life cycle inventory are then used in a life cycle impact assessment, which is the process of assessing the effects of the environmental findings identified in the inventory component. The LCIA ideally should address ecological and human health impacts, as well as social, cultural, and economic impacts.

Finally, the life cycle improvement analysis identifies opportunities to reduce or mitigate the environmental impact throughout the whole life cycle of a product, process, or activity. This analysis may evaluate improvements such as changes in product design, raw material substitution, industrial process improvements, or waste management methods.

This work is focused in the process of the plant where the process itself, operation and maintenance are highly influenced by human actions.

C. *Biofuel plants*

Biofuel are not cheaper than the derivates of petroleum. It is because the raw material of these does not have to be produced.

In an industry an accident can be fatally and biofuel plants are not exempt.

Being an industrial facility, risks and dangers exist related to:
1) transport, storage and use of great amount of toxic chemical substances and
2) flammable and highly polluting vegetal oil tanks.

A variety of accidents produced in biofuel plants are presented in the following sections.

D. *Biofuel in Argentina*

In Argentina the law contemplates:
1) the obligatory cut of 5% as of year 2010;
2) fiscal incentive for companies;
3) promotion of the small and medium companies and farming producers.

Due to the proximity of the year 2010 a lot of plants are been installed but do not exist a whole knowledge about the biofuel cycle.

It is necessary the development of specialized entities that have an interest in the use and exploitation of Bioenergy, and to assist them in the production of energy crops (topinambur, rapeseed, jatropha, sunflower, poplar, etcetera) to obtain biofuels, conduct quality controls and put them on the market. The synergy of the projects is constituted in the Bioenergy Program of the Cuyo National University joint to other institutions. This Program represents an advantage to both privately owned and Estate-run institutions, which can thus get qualified advise on any of the Program-related topics or participate in the Program by integrating their needs into the objectives of certain specific projects and consequently benefit from very specific technological definitions, which have been thoroughly studied and validated on the basis of real experience.

II. Human errors types

The authors agree with A. G. Foord & W. G. Gulland [4] -[5] -[3] who argues that it would not be possible to design technological systems to eliminate all human errors during operation because people are involved in: specifying, designing, implementing, installing, commissioning and maintaining systems as well as operating them.

Thus to improve process safety it will be necessary to focus on behavior and methods of working during all phases of the lifecycle so as to remove or reduce opportunities for human error.

Basically, human errors can be classified in two types of errors: errors by omission and errors of commission [6]. Both were found in accidents gathering in this work.

A. *Errors by Omission*

The errors defaults are those originated in the loss of a step (i.e. an instruction) within a sequence of steps for the accomplishment of a maintenance activity. The loss of this step can lead to deficient arming (e.g. is not placed in its place an element that prevents filtration, or that maintains assured a piece, etc.). Deficient arming, in an equipment standby cannot be pronounced during the later test to the maintenance activity but that can even require a period relatively prolonged of operation or a series of periods of operation. The errors default, are not noticed by the personnel and they are not made to intention.

B. *Errors of Commission*

The errors of commission are born of a cognoscitive activity of the personnel. They can be originated by the necessity to gain time (e.g. before to finish a task to be able to initiate another one, to finalize the day of work, to fulfill the requirements of yield of the supervisor, etc.). The technician feels enabled to make decisions on the best form to make an activity. This confidence is born mainly of its experience with the equipment. An error of commission is a joint action or of actions that leave to an equipment with a latent fault, which can be showed when the action of the same one is required. The error of commission is not noticed by the personnel who make it although he understands that he does not make the prescribed procedure.

The activity of supervision on a technician has among others the mission to limit the possibility of errors of commission, like only active measurement against those.

C. Errors found

Of the analyzed accidents is common to find the lack of safety measures. An inadequate design related to ventilation has caused the personnel poisoning. The lack of personnel training can lead to fatal accidents.

In some cases was noted the lack of procedures to manage dangerous substances.

A lot of cases where negligence, like to weld a full tank of fuel. This accident produced the death of a human been.

In most of the cases omission or commission errors have finished in a fire of the facility.

In the following section five cases are analyzed.

III. Study case 1: Fire caused by a methanol spill

A. The scene

The accident [7] happened outside of the plant building. During a transfer of methanol a probable cause of static electricity was the ignition source.

The plant was in full production mode when the outside fire spread into the building. The operators followed their training and safety procedures and quickly shut down operations.

The plant burned violently for several hours. No other buildings were affected because they were not in close proximity.

B. Events sequence

- The plant was in full production mode.
- Two operators were carrying methanol in gallons of 1 tn.
- A gallon falls.
- The aluminum strikes the concrete.
- Sparks are generated.
- A small spill occurred that ignited.
- Operators shut down the plant.
- Use of on-site extinguishers.
- Extinguishers fail.
- Fire brigade is notified.
- The plant burned for several hours.
- Non-hazardous plumes of smoke could be seen for miles.

C. Consequences

- Nobody was injured.
- As a result, although the entire plant was destroyed.
- Biodiesel tanks and gallons of methanol were saved.
- No other buildings were affected because they were not in close proximity.
- There were a total loss of the building and equipment.

D. Errors found

- Lack of an earthing of the tanks to avoid static loads (omission error).
- Deficient manipulation during the transfer of methanol (negligence).
- Use of metallic tanks with unsafe locked (commission error).

IV. Study case 2: Explosion of a gallon steel

A. The scene

Personnel had been retrofitting a formal fruit-packing plant [8]-[9]-[10] and were just beginning full-scale production. The plant would have produced 1 MMgy of biodiesel from multiple feedstocks.

A storage tank was welding contained an unknown quantity of fuel when the explosion set off another blast of flames that rapidly enveloped the building, causing tanks containing glycerin, among other flammables, to explode. The tank room and boiler rooms of the plant were destroyed. The building was an old, cold storage facility, and the ceiling was about a foot thick with foam and different kinds of insulation.

B. Events sequence

- Retrofitting a fruit-packing plant to a biodiesel plant.
- A worker was welding a storage tank of fuel.
- The tank explodes.
- Blasts of flames envelope the building.
- Tanks containing glycerin explode.
- The welder is dead.
- A worker tried in vain to rescue the welder, meanwhile sustaining second degree burns and suffering from smoke inhalation.
- Firemen responded to the fire.

C. Consequences

- The welder is dead.
- A worker is victim of second degree burns and smoke inhalation.
- The tank room and boiler rooms of the plant were destroyed.

D. Errors found

- Lack of fireproof materials (omission error).
- Rescue action without training (commission error).
- Neglected actions (to weld a fuel filled tank, lack of safety procedures and lack of supervisor personnel)

V. Study case 3: Fire caused by biodiesel spill

A. The scene

A fire begins in a small biofuel plant [11]- [12]. Firemen arrived to the site but they did not know that nearly 1,000 gallons of biodiesel were stored in and around the building. Heavy black smoke can see out of the building.

Before the fire was extinguished a barn and processing and storage equipment were total loss.

The firemen prevented the blaze from spreading to a pickup truck held barrels containing hundred of gallons of biodiesel.

B. Events sequence

- The fire began in the electric wiring of the barn.
- 500 gallons of biodiesel burn.
- Firemen battled the fire during 45 minutes.

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C. Consequences

- The barn was a total loss.
- Processing and storage equipment were total loss.
- There weren´t human been injured.

D. Errors found

- The office where the fire started was not up to building codes (omission error).
- The wiring was old and the office was separated from the rest of the barn by wooden paneling, not fire-resistant (negligence).

VI. Study case 4: overheating of plant equipment

A. The scene

Fire in the roof and ceiling of an Ethanol plant [13]-[14]. About 60 firefighters worked the blaze by ripping parts of the roof off. Odor-reduction equipment known as a thermal oxidizer overheated and caused a fire in the insulation of the roofing and ceiling material.

B. Events sequence

- At the beginning there was a brewery.
- The brewery was expanded to include the addition of a plant to recover and market the carbon dioxide which is a significant byproduct of ethanol production.
- An accidental overheating of the thermal oxidizer was produced.
- A piece of insulation fell into a heated area setting the roof on fire.
- Fire spread on roof and ceiling material.
- About 60 firemen worked the blaze by ripping parts of the roof off.

C. Consequences

- A fireman was hospitalized after the fire.
- It is estimated damage between $ 10,000 and $15,000.
- There weren´t workers injured.

D. Errors found

This is a negligence typical case. It was the fourth fire at the plant since it opened three years ago.

In response to numerous community

One of the previous fires also started when the thermal oxidizer overheated. The other two were in the plant´s grain dryer.

VII. Study case 5: FMEA on a discontinuous distillation plant

In order to improve the design and operation of biofuel plants a Failure Mode and Effect Analysis was conducted on a Discontinuous Distillation Plant (see Figure 2).

Failure modes and effect analysis (FMEA) is a procedure to analyze failure modes and classified them by severity. It is a systematic process for identifying potential failures before they occur with the intent to eliminate them or minimize the risk associated with them [15]- [16].

The plant is composed by:

– Boiler of 250 liters (10 KW)
– Column of filling structured of 4” xs 2.5 ms (18 - 20 theoretical stages)
– Condenser of helmet head and tubes - 0.22 m2
– Condensated buffer
– Vacuum system (5-10 mmHg)
– Distilled reception tanks

Account with a security system made up of:

– Safety valve
– Presostato
– Pushbutton in plant for total cut
– Fire protection system

This plant was built to be use in teaching, research and services.

It is a membership of the Bioenergy Program developed at Engineering Faculty, Cuyo National University.

As a result is important to note the contribution of the human error to this type of Plants and the spark production and static electricity to the risk.

These results are consistent with data gathering in real cases.

It is detected that it is important take into account all measurements variables improving and added instrumentation.

VIII. Remarks

It is not unusual for fires that start in one portion of a structure to spread to a portion containing flammable materials – even in private residences.

Figure 2. Discontinuous distillation plant

At present, transporting biofuel, particularly methanol, via pipeline is not completely viable. Ethanol is highly hydrophilic and potentially corrosive.

Rail transportation is one of the simplest methods of moving biofuel.

To get employees involved and to train them to use a simplified risk analysis as well as to make a simplified risk assessment is another very important step to prevent accidents, diseases and fires [17].

A sub-set of the Human Reliability Analysis is errors of commission [15]. These types of human error are very frequent in industrial activities. The study of the models able to foretell the probabilities of the personnel of an installation to commit errors of commission is an open subject internationally.

Although advances related to the modeling of errors of commission have been made a general consensus about the form of modeling and its quantification does not exist.

An important branch of the investigation centers its efforts in the study of the sociological and psychological components of the subject. Other branches focus their attention on the study of the consequences and the contexts (layout, type of procedures written, organization, etc.). A new approach is the application of simple models based on the Theory of Games. This approach has the possibility of evaluate human tendencies at different situations.

IX. Results discussion

In this section is presented (see Table 1) the errors found. This table shows the kind of errors found in each one of the cases analyzed.

Only in case 4 there is negligence without other types of errors.

Table 1. Comparative table of results

	Commission Error	Omission Error	Negligence
Case 1	X	X	X
Case 2	X	X	X
Case 3		X	X
Case 4			X
Case 5	X	X	

All the accidents are due to the belief that in such simple process is impossible to have troubles. This belief is a constant in all kind of industries and much more in biofuel plants where the lack of experience and the simple process are combined to prepare the environment to produce errors.

From this point of view a new technique is adequate for these cases. In 2000 the Nuclear Regulatory Commission of the United States displays ATHEANA [18]-[19] (Technique Human Event Analysis) a methodology that incorporates the contexts like generating sources of error.

The ATHEANA HRA method is being developed to provide a way for modeling new types of human errors with an emphasis on so-called errors of commission.

The underlying basis of ATHEANA is that significant unsafe acts by humans occur as a result of combinations of influences associated with the plant conditions and specific human-centered factors that trigger errors by plant personnel.

The ATHEANA method is shown in Ref. [19]. It was thinking from the nuclear area and it is based on a series of very simple premises as follow:

– when required to respond to abnormal conditions in nuclear power plants, the operators' actions are based logically on their understanding of the conditions in the plant;
– the operators' understanding of conditions in the plant is produced by the evidence presented to them through the human–machine interfaces, their awareness of plant activities, and their knowledge of the behavior of plant systems;
– the operators' understanding of the state of the plant can be misled by combinations of plant conditions and weaknesses in the human-machine interface or gaps in job aids like the training and procedures under those plant conditions;
– the operators' misunderstanding of the plant state can lead them to take inappropriate actions, which can include actions to terminate operating equipment;
– this can involve a series of actions under dependent conditioning, despite a series of cues that otherwise could not be missed.

Identifying and assessing the likelihood of these inappropriate actions are the primary goals of the ATHEANA method.

X. Conclusion

Biodiesel is made from vegetable oil and can be used in diesel engines, either mixed with conventional diesel fuel or in pure form. It produces far less air pollution than conventional diesel fuel or gasoline.

It is a non toxic substance but the process may be dangerous if it is not tried as another chemical process.

Dangerous materials like methanol can be spilled and can generate explodes if it is not have adequate manage.

One of the unfortunate byproducts of the production of ethanol is the odor emitted from the production process. It is important to eliminate them considering the security.

It is important take into account the lack of training in safety of the personnel.

Frequently, safety is omitted due to the simplicity of the process.

It is necessary apply secure technology and expert knowledge.

It is highly recommended to do an FMEA in order to improve the safety of the facility and to diminish the human error to implement reliability human analysis.

Due to the main concern with accidents in this kind of plants is highly recommended to apply ATHEANA method in order to diminish commission errors.

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