Improving the Safety of Biogas Production in Europe

Mejoramiento de la seguridad de la producción del biogás en Europa

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Key words
Biogas, safety, regulation, risk management.

Abstract
The production of biogas is positioned as energy which can not only generate a source of renewable energy but also which recycles waste. In the context of sustainable development, the place of biogas is therefore essential. Several questions about safety issues, the harmonization of the regulations and the need to develop standards are discussed in this paper, based on the results of a workshop on biogas safety and regulation organized in November 2010 and the activities of the European Working Group on Biogas Safety and Regulation created after the workshop. The risks corresponding to the biogas production and use have been framed using iNTeg-Risk method and tools. Several deficits for risk management have been identified and a strategy to improve risk management proposed by the working group is presented at the end of the paper.

Palabras claves
Biogás, seguridad, regulación, manejo de riesgos.

Resumen
La producción del biogás se ha posicionado como energía que no solamente genera un recurso de energía renovable sino también que recicla desperdicio. En el contexto del desarrollo sostenible, el lugar del biogás es por lo tanto esencial. Algunas preguntas de temas de seguridad como la armonización de las regulaciones y la necesidad de desarrollar estándares se discutirán en este texto basados en los resultados del taller sobre la seguridad del biogás y las regulaciones organizado en noviembre del 2010 y las actividades del grupo de trabajo europeo sobre la seguridad del biogás y la regulación creada después del taller. Los riesgos correspondientes a la producción del biogás y su uso han sido enmarcados usando el método y las herramientas iNTeg-Risk. Varios déficits para el manejo de riesgo han sido identificados y, a su vez, el grupo de trabajo presenta una estrategia para mejorar la gestión de riesgos al final de este trabajo.

Introduction

Biogas is a promising energy resource in the context of the new European Energy Strategy 2020. It represents a valorization of wastes (water or biomass) and can be produced all over Europe for a great variety of applications: transport, stationary energy use, heat and combustion.

The main emerging risk issues related to the quick development of biogas, which is flammable, toxic, and possibly pathogen (microbiological hazard), are as follows:

- The diversity of processes (from waste water treatment to solid waste treatment, or biomass valorization by farmers) without reference document clearly defining at international level the state of the art regarding safety,
- The lack of clear regulations and standards regarding the safety of biogas production and use, and the lack of enforcement of the existing occupational health and safety regulation (including ATEX),
- The lack of organized communication channels to share the experiences (near-misses, accidents, and also positive experiences) between the industry players, but also with the usual stakeholders such as authorities, insurance companies, the public.

N.B. The smell of biogas, often considered an environmental issue is not addressed specifically in this document.

The European Working Group on Biogas Safety and Regulation (EWGBSR), created after the Workshop organized by EU-VRi and INERIS in Paris in November 2010, has joined the iNTeg-Risk project in 2011. This

project provides a framework, methods and tools to begin structuring the sector from a risk management point of view.

Participation in the project means having "Biogas safety and regulation" as a new ERRA (Emerging Risk Representative Application) whose objective is to accompany the deployment of biogas in Europe with a high level of safety. It means that the approach and tools developed within iNTeg-Risk have been implemented in the working group. These methods and tools are helpful in managing the emerging risks of biogas and they constitute a full test of the results of iNTeg-Risk project.

This paper presents the ideas developed in a "briefing paper" prepared by the EWGBSR. It describes the emerging risk issues related to the production of biogas. The objective of the "briefing paper" is to raise awareness about the emerging risks among policy makers and risk managers at corporate level. It is aimed at providing the target group with synthetic information on safety issues related to biogas about possible solutions based on the implementation of the iNTeg-Risk solutions, which may, therefore, support the launch of further initiatives on biogas risk management.

First of all, this paper provides a general presentation of the trends of biogas production in Europe and the legislation currently in force. Secondly, the main biogas safety issues are presented as well as the trends in terms of accidents in Europe. Third, the application of the iNTeg-Risk approach and tools is described some proposals for improving risk management are given.

Biogas development and European policy context

Background Information

Biogas is a fast-developing energy resource in Europe. In 2010, primary energy production from biogas enjoyed an annual growth of 31.3% to reach a production of 20.9Mtoe [5].

Biogas has numerous uses. from the direct use of energy in the plant, to the injection in the (bio-)natural gas grid, to produce heat and electricity or to be used liquefied. The uses are presented in the Figure 1.

There are three major production channels:

- Sewage sludge gas represents 9.8% of total production (1.1 Mteo).
- Landfill gas represents 26.8% of total production (2.9 Mteo).
- The remaining 63.4% are produced from other deposits which cover purpose-designed energy conversion methanization plants (decentralized agricultural plants, municipal solid waste methanization plants, co-digestion and multi-product plants).

This important increase in biogas production benefited mainly:

- Electricity production that represented 30.3 TWh in 2010 which is 20.9% up on 2009.
- Total heat consumption (from the transformation sector and for self-

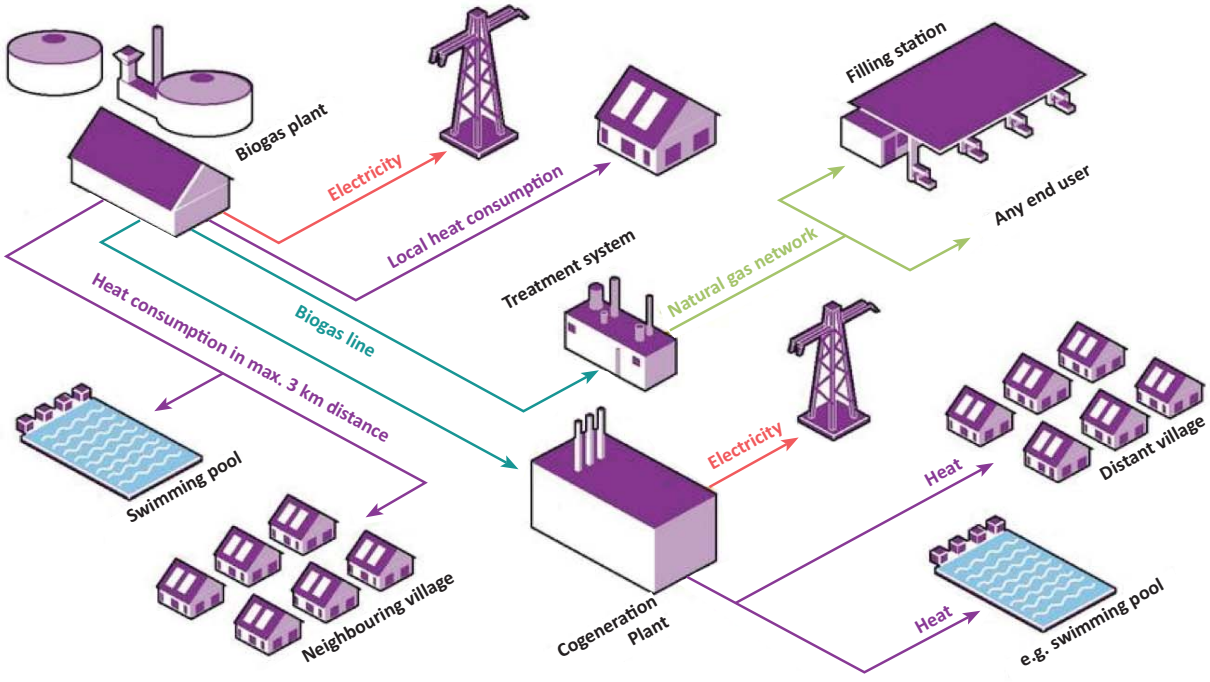

Figure 1. The Various Uses of Biogas
Source. EBA, European Biogas Association

consumption by the end-user) that amounted to 1.5 Mtoe.
- Another type of biogas recovery, biomethane injection (purified biogas) into the natural gas grid that is booming in a number of countries such as Germany, Sweden, and the Netherlands. The development of "fuel-grade biogas" (natural gas quality) provides another possible opening.

The EurObserv'ER survey indicates that the member states are already ahead of their electricity target and in line with their heat consumption forecasts. Indeed, the National Renewable Energy Action Plans (NREAPs) target a production of electricity from biogas source up to 64 TWh in 2020 (43.9 TWh in 2015 and 28.7 TWh in 2010) and biogas heat is targeted to reach 4.5 Mtoe in 2020 (2.7 Mtoe in 2015 and 1.5 Mtoe in 2010).

However, much of the growth in primary energy production from biogas is happening in Germany (61% of the primary energy production). Contrary to the others, Germany has made the choice to promote the use of energy crops.

Political decisions to develop the biogas sector, both in regulation and financial terms are crucial if the targets are to be met, but the public acceptance of the new energy systems is also an important component that has to be seriously taken into account.

Biogas Production

Biogas is produced from waste in biogas plants or anaerobic digesters [6]. The anaerobic digestion is the process which transforms organic matter into biogases such as methane and carbon dioxide. There are several processes for the production of biogas depending on the type of organic waste used. Indeed, biogas could come from several sorts of raw materials:
- Sewage sludge
- Food waste
- Waste from food industry
- Manure from cows, pigs etc.
- Residues from agriculture
- "Energy" herbs and plants such as maize
- Distillery by products
- Organic fraction of municipal solid wastes

The amount of biogas or the quality of the biogas which will be produced depends on the sort of raw material. Thus, biogas production is extremely variable from one plant to another. It is also important to highlight the difference between a biogas plant and an anaerobic digester (biogas from landfills and biogas from digesters).

There are many technical aspects which depend on each other: Various raw materials require different processes, different processes mean different amounts of gases, and different amount of gases mean different sorts of up-grading or removing. And finally, it appears impossible to fix a global yield in order to study all uses of biogas or to clearly identify hazards and risks in a biogas plant.

Thus, it is important to understand the critical safety parameters and to establish a regulation on the production of biogas or to think about a possible standardization that is compatible with the variety of biogas production plants.

Energy Policy Context

The safe development of biogas in Europe will be possible with a strong legislation to support its production. This paragraph maps the landscape of EU policy.

The driving force behind the development and use of bioenergy is the Renewable Energy Directive (Directive 2009/28/EC) adopted in April 2009 by the Council and the Parliament of the European Union. This directive sets a common framework for the promotion of energy from renewable sources in Europe. The aim of this legislative act is, by 2020, for 20% of the EU's total energy consumption to be from renewable sources and for 10% of the energy used for transport in each member state to be from renewable sources.

The implementation of these objectives is supported by the European Strategic Energy Technology Plan (SET-Plan), initially settled in 2007 by the European Commission (COM(2007)723). The objective was to increase, coordinate and focus EU support on key low-carbon energy technologies. There are 6 European Industrial Initiatives (EIIs) in the SET-Plan, including the European Industrial Bioenergy Initiative. The EIIs bring together the industry, the research community, the member states and the Commission and aim to rapidly develop key energy technologies at European level. Simultaneously, the European Energy Research Alliance (EERA) works to align the R&D activities of individual research organizations to the needs of the SET-Plan priorities, and to establish a joint programming framework at EU level. The SET-Plan is coordinated by the SET-Plan Steering group (SET-Group) and supported by European Commission's Information System for the SET-Plan (SETIS).

A global strategy insisting on safety aspects has been established in the Communication "Energy 2020 - A Strategy for Competitive, Sustainable and Secure Energy" (COM(2010)639). This Communication sets out the energy priorities for the next ten years and sets the actions to be taken in order to tackle the challenges of saving energy, achieving a market with competitive prices and secure supplies, boosting technological leadership, and effectively negotiating with our international partners. The strategy is structured around four priorities. Priority 2 & 3 specifically set high requirements in terms of the development of safe technologies in an appropriate and effective regulatory context, reaching the public acceptance of the new energy technologies.

The importance of biogas has been more particularly pointed out in the resolution on sustainable agriculture and biogas (2009/C 66 E/05) of March 12th 2008 The European Parliament emphasizes the importance of biogas as a renewable energy resource for the future. This resolution highlights the benefits of biogas, as well as several

Table 1. Trace Compounds of Biogas from Different Biogas Production Plants

Biogas	CH4 (%)	CO2 (%)	O2 (%)	N2 (%)	H2S (ppm)	Benzene (mg/m^3)	Toluene (mg/m^3)
Landfill	47–57	37–41	<1	<1–17	36–115	0,6–2,3	1,7–5,1
Sewage digester	61–65	36–38	<1	<2	b.d.	0,1–0,3	2,8–11,8
Farm biogas plant	55–58	37–38	<1	<1–2	32–169	0,7–1,3	0,2–0,7

Note: b.d.: below detection

threats on health and the environment linked to biogas production. It also makes a number of recommendations to the Member States and Commission:

13. Stresses that technical and management developments are expected in the near future which will further increase environmental and health benefits of biogas installations which use livestock manure, slurry and organic waste;

The European Commission is also asked to provide support and in particular to enforce legislation for the development of biogas installations. Concerning safety aspects, the importance of reporting and sharing experience on best practices between Member States is emphasized:

39. Urges the Commission and Member States to develop a coherent biogas policy; asks the Commission to present a specific report on biogas and its promotion in the EU, outlining the necessary changes in Community and national law to facilitate further expansion of the biogas sector and pointing out the most efficient ways of using EU funds and programmes, as well as giving best practice examples; asks also, in this regard, for an impact assessment of the various forms of biogas production on climate, the ecology of the landscape, rural incomes and worldwide security of food supply;

50. Calls on the Commission to ensure cooperation and coordination between Member States, including those who currently have no biogas installations, or just a small number thereof, so that they may learn about each other's best practices in relation to biogas installations through the sharing of knowledge and technology;

Regarding the policy context, it highly prioritizes renewable energies, in particular those that can be produced locally and in a distributed manner, such as biogas. At the same time, the shift to renewable energy has to be safe and secure. The infrastructures have to be adapted as well as the regulatory context.

It means for biogas, that the following challenges must be solved:

- Ensure the inherently safe design and operation techniques of biogas plants and usages
- Reach the public acceptance of this renewable energy
- Capitalize the good practices in reference documents (guidelines) and in standards
- Support the development of a harmonized and cost-effective regulatory framework.

Biogas safety issues

Main risks for biogas production

Biogas production plants present three main risks:

- The risk of explosion is the most rigorously studied as it is related to the production and use of a flammable gas which is made up mainly by methane (cf. Table 1).
- The second major risk is toxicity due to the presence of H2S, which is a very toxic gas produced in anaerobic digestion.
- The microbial risk is also to be considered; however, chronic risk of inhaling pathogens and minor elements when using biogas is overshadowed by the two previous risks.

The construction of a biogas plant and its maintenance should be well monitored in order to manage risks. Prevention of people from being exposed to those risks and checking of all materials (including corrosion) should be realized with the aim of making the production of biogas safer.

Analysis of Accidents Involving Biogas

A census of databases collecting accident analyses of biogas production was conducted in 2011 by INERIS for the Ministry of the Environment in France. The aim was to gather comprehensive feedback on the methanization activity from different national and international databases such as the databases ARIA from BARPI in France or ZEMA in Germany.

The INERIS [1] study provides, for the first time, a detailed analysis of accidents in France and in Germany. For example, 140 accidents were identified in Germany in 2009. The study describes the most probable scenarios and gives an indication of the severity of the past accidents.

It appears, from the study, that most accidents that have occurred were fires and, in most cases, their causes have not been identified with certainty.

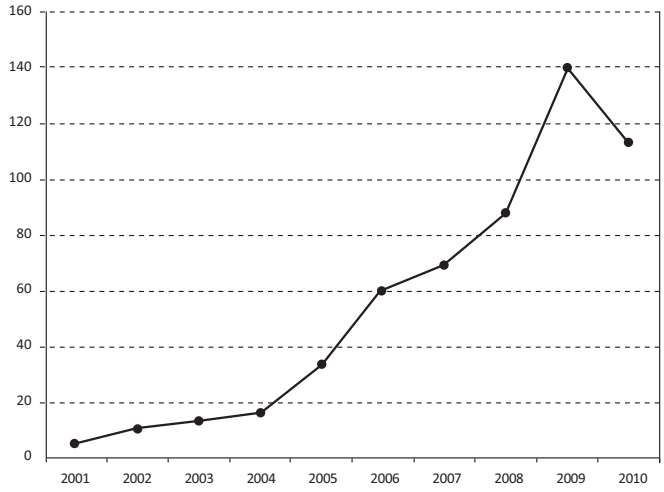

Figure 2. Number of Accidents on Installations Producing Biogas in Germany

The evolution shows that accidents are better controlled and consequently with smaller effects on and off site. Most of the reported accidents occurred within the storage area of the biogas plants. From the cases reported, no significant impact on the environment was recorded, side effects were mostly small. The only consequence of fires outside biogas plants are related to the formation of smoke plumes from burning waste.

Typical incidents in biogas plants are listed below:

- leakage in the storage tank and / or on the distribution network of the biogas,
- leakage following the completion of work on site storage and distribution of biogas,
- accidental release of H_2S especially in mixtures of septic waste,
- water pollution caused by effluent discharge,
- overflowing sewage systems or storm-water control due to exceptional downpours, to equipment failures in the event of massive influx of water fire suppression,
- presence of dangerous products in the raw material used to produce biogas,
- overflow, freezing of valves, high pressure inside the digester.

The incident assessment shows that the functional units such as CHP plants, injection system of solid, pumps, pipes and valves and agitators, are particularly vulnerable, implying failures on safety system (loss of containment, leakage).

In general, the process of anaerobic digestion of biomass and waste generates a high risks probability (and health and environmental extension) during the course of operation and / or maintenance.

The main hazards to consider are listed in order of priority in terms of occurrence probability: fires, explosions, toxic gas emissions (H_2S).

Compliance with ATEX regulations and the drafting of document related to protection against explosions is a significant measure to control such risks in the methanization sector. It is, therefore, necessary to ensure, depending on the biomass used, protection against explosion of flammable gases (CH_4, CO, H_2S and H_2), protection against fire and protection against the emission of toxic gases (including H_2S).

Evolution of the regulations dealing with safety in several member states

In 2011, the European Working Group on Biogas Safety and Regulation developed a survey focusing on the following questions:

- Are you aware of recent evolutions of the biogas regulations in your country?
- Are you aware of technical guidelines related to safety at national or European level?

This survey, that collected answers from 14 national experts from 6 different countries, provided an interesting overview of the situation in Europe. According to the results, it appears that a few regulation and guidance documents exist, but they are either too generic (e.g. SEVESO), or too specific (e.g. technical guideline for biogas transportation). Moreover, the implementation of safety regulations on biogas plants is not harmonized throughout Europe.

Thus, there is a real need for a common framework that can be applied for all production processes, all raw materials and all types of producers.

Implementation of INTEG-RISK approach

Use of iNTeg-risk tools to frame the problems

Problem framing is a qualitative step necessary to start developing risk management solutions. It places particular importance on the need for all interested parties to share a common understanding of the risk issue(s) being addressed or, otherwise, to raise awareness amongst those parties on the differences related to the perceived risks.

The project has produced a framework and tools, such as a template to carry out a common analysis of the various case studies. The use of the template provides an overview of the emerging risk issues of the case under consideration. The following aspects are systematically described:

- General description
- Source of hazard
- Elements at risk to hazard
- Hazardous situation
- Main stakeholders
- Early warning situations
- Status description

Table 2. The Different Steps to Framing the Risk Management Problems for Biogas Production

General description	Biogas differs from gas in petrochemicals due to three main characteristics that are important to take into account: • Biogas has been developed in various sectors, very different safety and industrial cultures • Biogas operators are often public companies or institutions with different rules and logic than private sector. • Biogas is a biological process, not a chemical process
Source of hazard	The source of hazard is mainly related to the composition of the biogas, which is a toxic, flammable and pathogenic mixture. The context can also play an important role.
Elements at risk to hazard	The elements at risk are mainly the operators but can be extended to the environment, the population and even the whole community depending on the plants size and location.
Hazardous situation	The hazardous situations are: • Explosion and fire • Toxic release • Microbiological release
Main stakeholders	The main stakeholders are the operators (public companies or municipalities) and the chain of operation (sub-contractors). • Public • Local public authorities • Regulator (central government)
Early warning situations	A recent study describes the most probable scenarios and gives an indication of the severity of the biogas accidents. The number of accidents has significantly increased in several member states (cf. Figure 1).
Status description	A European Working Group on Biogas Safety and Regulation (EWGBSR) has been created in 2010 and is operating to bring more evidences on the risk management issues for the biogas production.

The table hereunder presents a summary of the various aspects that help to frame the emerging risk issues for biogas.

Stakeholders and their concerns

It appears that the stakeholders involved in biogas production have very different visions and concerns about biogas, rendering difficult any consensus on the evolution of this sector. Concerns should converge and find common solutions in order to further develop biogas production.

Identification of deficits

The risk management deficits for biogas production have been characterized using the set of tools developed with the iNTeg-Risk project. These tools have been extensively described in the proceedings of the three last annual conferences (Jovanovic et al., 2010, 2011, 2012) [2, 3, 4]

Proposal for improving risk management

Specific Elements for Risk Management

The development of a risk management strategy has to take into account the specific features of the biogas industry, which is in fact derived from several industry sectors, i.e. in particular:

- Waste water treatment industry
- Solid waste treatment industry
- Agricultural industry.

These sectors are structured differently, have different actors and a different set of standards and regulations. These aspects are considered in the following paragraph.

Industrial Rationale:

- At the origin, Biogas is rarely the objective of the process, but often a sub-product which is sometimes even considered a “waste gas”. For example, in a waste water treatment plant, biogas is the sub-product of the digestion process, the objective of which is to reduce volume and weight of the waste extracted from water.
- Except for specific methanization plants, the biogas process is rarely the main process of the plant, but only a part.
- Even if the methanization process could be a critical one (ex: in WWTP), the use of biogas is rarely critical except from a financial point of view (ex: when it must be replaced by natural gas in boilers).

Therefore, if biogas production fails to be considered a safe and smart process, it might be withdrawn.

Technical Standards:

- As experiences and contexts between the sectors of operation vary, the technical responses also vary. These different technical answers could even give rise to differences of technical evidences. For example, using pipe in stainless steel can be considered evidence in the WWTP sector, but, in rubbish dump sector, HDPE is considered evidence.

Table 3. List of Stakeholders and their Concerns

Stakeholder	Concerns
Public operators	Control the cost of the main activities (waste or water treatment) Business continuity Operational costs
Operating company	Health and safety of the employee Business continuity Operational costs Diversity of process and options for the safety design
Operator (agricultural)	Health and safety of the employee Business continuity Operational costs
Local public authorities	Health and safety of the employee Business continuity Protection of the citizens
Public in general	Cost of energy
Public in the vicinity of the biogas plant	Odour Impact of accidents
Public authorities (regulator)	Long term sustainable operation Minimizing the risks for the society Cost effectiveness of the biogas sector

- There are differences of opinion in terms of the commonly accepted level of MTBF or MTTR of the same equipment (ex: gas compressor, gas monitor), depending on the criticality. These differences between the levels of acceptability have a strong impact on the quality of the products proposed by the suppliers.
- Methanization is a biological process with a great inertia. Therefore it cannot be stopped like a classic chemical process can. So, safety equipment and safety concepts must absolutely take this particularity into account without simply copying what is done in petrochemicals.

For example, in order to prevent a risk of explosion by introducing air in the methanizer, you could have some conditions which order its isolation. But with its inertia, methanizer will continue to produce biogas and pressure will increase until the safety valve opens, releasing the gas to the atmosphere.

Table 4. Deficits Identified for Biogas Risk Management

	Pre-assessment	Risk Appraisal	Tolerability & Acceptability Judg.	Risk Management
T: Technical / Techno-logical	Pretty good knowledge on the hazards of biogas	No enough data available on the various situations for biogas production	Lack of monitoring / indicators about incidents and accidents	Lack of specific technical guidance documents for safety
H: Human / Management	Lack of education and safety culture	Lack of risk perception studies	No criteria available of risk tolerability.	Lack of channels to share experience on incidents and accidents
C: Governance / Communication	Lack of awareness is observed	Lack of concern assessment	No discussion on risk acceptability has taken place.	Lack of communication on the hazards and residual risks
R: Policies / Regulations / Standards	The problem is not yet clearly framed	No cost-benefit analysis and socio-economic impact	Lack of acceptability criteria	Lack of harmonized regulation with a clear doctrine On-going initiatives in some countries to set up a safety regulatory framework

Regulations:

- When they exist, Biogas regulations have been developed around the already existing regulations for the main activity of which biogas is issued. For example, in France, methanization reactors of WWTP are not regulated by the industrial risk regulations, but the water ones.
- Authorities in charge of monitoring activities of biogas operators, prioritize their action towards the core activities of biogas producers such as waste management or water quality.

Therefore, regulations could be contradictory and authorities are not properly equipped to complete their mission of prevention.

Safety Culture:

- In contrast to petrochemicals—where industrial risk management is an integrated part of their activity in each step of process—biogas operators have to face such risks only in a small part of their activity. So, they do not master the different tools used in risk management such as HAZOP. We can even affirm that they are not really comfortable with the principles of industrial risks management.
- Sectors in which biogas is operated, are internally linked around their main issues such as land efficiency for agriculture or town planning policy for municipals. But they do not share their experiences in terms of biogas with each other.

In these conditions, a collective learning process has to be developed to improve the safety culture in the biogas industry. The current low level of safety culture and risk awareness prevents the establishment of adequate harmonized minimum safety requirements all over Europe and in the various sectors of biogas. Raising the safety culture level is therefore a priority.

Proposal for a Tailor-Made Approach to Improve Risk Management

In order to support the collective improvement of the safety level, the biogas industry sectors need to prepare a series of reference documents and guidelines. The following documents and initiatives should be prepared as a priority, with the support of experts from industry and research organizations, specialized in industrial safety.

- A European general guideline that contains information on biogas production technologies, the regulatory context of biogas plants and advice on managing the establishment of a biogas plant.
- A European database containing information on accidents, incidents and near-misses providing an overview of the event with standardized information with the ability to search and filter the content by key words, technologies, contexts…
- A catalogue of proven technical solutions on piping class, demonstrated instrument technologies, severe conditions recommendation, specifics Process Flow Diagram.
- A methodological guideline for the design of each type biogas plant with a presentation of the main accidents and their causes, a reminder of the specific questions or traps related to biogas and recommendations on the Process Flow Diagram.
- A methodological guideline for biogas plant operation containing a presentation of the main accidents and their causes and information on the recommended controls and recommended methodologies to stop or start biogas equipment safely.
- A European specific regulation on biogas production and uses defining the minimum safety design and equipment required, as well as the minimum operation procedures required and the organization of the monitoring.

Conclusion

Biogas is a very promising source of renewable energy that presents several hazards such as fire, explosion, toxicity and microbial contamination. This paper presents an overview of the safety situation of biogas production. After a review of the production process, the trends in Europe, and the legislation in force at European level, risks related to biogas production have been described. It is essential to properly frame biogas safety issues in order to improve risk management. Therefore, iNTeg-Risk tools, which provide an effective framework, have been implemented for biogas to help frame the problems and develop a risk management strategy.

As a consequence, a series of documents and initiatives have been proposed: a European general guideline; a European database on accident; incident and near-misses; a Catalogue of proven technical solutions; a methodological guideline for the design of each type biogas plant; a methodological guideline for biogas plant operation; a specific European regulation on biogas production and uses.

These actions will be set up by the EWGBSR in order to improve biogas risk management and consequently support the further and safe development of biogas in Europe.

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