SAFETY MANAGMENT IN THE TRANSPORT OF DANGEROUS SUBSTANCES THROUGH PIPELINE

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SUMMARY

Pipelines are an important, and sometimes a vital, means of transport of a variety of hazardous substances such as crude oil, its derivatives and natural gas. In general, they offer a practical and economical means to transport large volumes of hazardous substances from their producer to a wide range of customers over long distances. Moreover, they have reliability and, if compared to other modes of transport, few associated impacts on the environment. For all these reasons pipeline networks are growing rapidly. The main disadvantages of pipelines are: high investment costs and a certain lack of flexibility in regard to delivery points and quantities of transported substance.

The use of well planned, constructed, properly operated and maintained pipelines generally represents a safe mode of transport both for the environment and human health. However, like fixed installations handling hazardous substances, in case of accidents, these may be a serious hazard to human health and safety and to the environment (especially soil and water). External interference is the most frequent cause of pipeline accidents in the EU (European Union) and UNECE (United Nations Economic Commission for Europe) region.

Although pipeline regulatory provisions and safety performance in certain ENECE countries has been developed to high standards, in the rest of the UNECE region there are important gaps relative to regulations and requirements concerning the safety of pipeline operation to prevent incidents and to limit their consequences for human health and the environment.

So, against the need both for further improvements and, as many pipelines cross borders between two or more countries, for harmonization across the UNECE region of the pipeline safety performance, there are activities at EU and UNECE level on the control of the hazards arising from transport of dangerous substances through pipeline.

On the base of these activities, the aim of this document is to give some key elements which are peculiar to pipeline safety management by both operators and competent authorities. A lot of these elements have been considered in the document "*UNECE safety guidelines/good practices for pipelines*"[1] that a group is drawing up within the two UNECE Convention on transboundary industrial accidents and on the transboundary watercourses use and protection. In consideration of the Italian pipeline network, mainly of the complex gas transmission system, Ministry for environment and land protection of Italy, appointing experts from the Institute for Atmospheric Pollution of the National Research Council, has attended to this UNECE activity in which has also involved Italian pipeline operators.

1. TRANSPORT THROUGH PIPELINE: DANGEROUS SUBSTANCES TRANSPORTED, ACCIDENT CAUSES AND CONSEQUENCES OF THE ACCIDENTS

Pipelines are essential systems of transport of hazardous substances over long distances in the UNECE region (figure 1.).

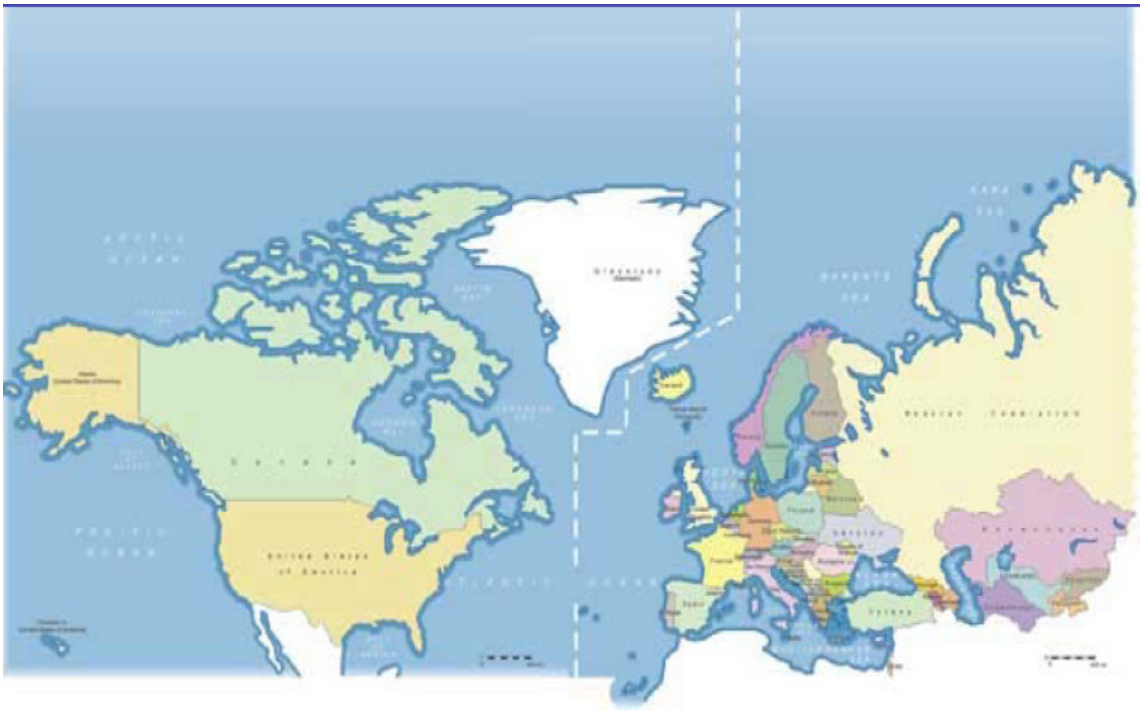

Figure 1. UNECE context

Crude oil, its derivatives and natural gas are dominant among the substances transported by region's pipelines. Other hazardous substances transported in pipelines include chemicals such as: Ethylene, Propylene, Chlorine, Ammonia, Hydrogen, Oxygen, Butadiene and Styrene.

Pipelines in general consist of systems with different functions. Besides the main body of the pipeline, these systems include receiving terminals, intermediate and delivery terminal storage, pumps, compressors, separation and off-takes, treatment, gathering stations, metering stations and other stations such as valve, supply or pigging-stations.

The advantages of pipelines comprise reliability, low operating costs and few transport-associated environmental impacts; but the most important advantage is that they can move large amount of dangerous substances quickly and across great distances. However, pipelines necessitate high infrastructure costs associated with construction, long-term to make a pipeline operational also due to the need to take appropriate routing decisions relatively to soil, water and human protection. Moreover, pipelines have the problems associated with the lack of flexibility in regard to delivery points and quantities that can be transported.

Transport of dangerous substances through pipeline networks clearly has a international rather than a national dimension. There are extensive pipeline networks in Europe, North America, Caucasus and Central Asia and pipeline networks are growing rapidly within the UNECE region (figure 2.).

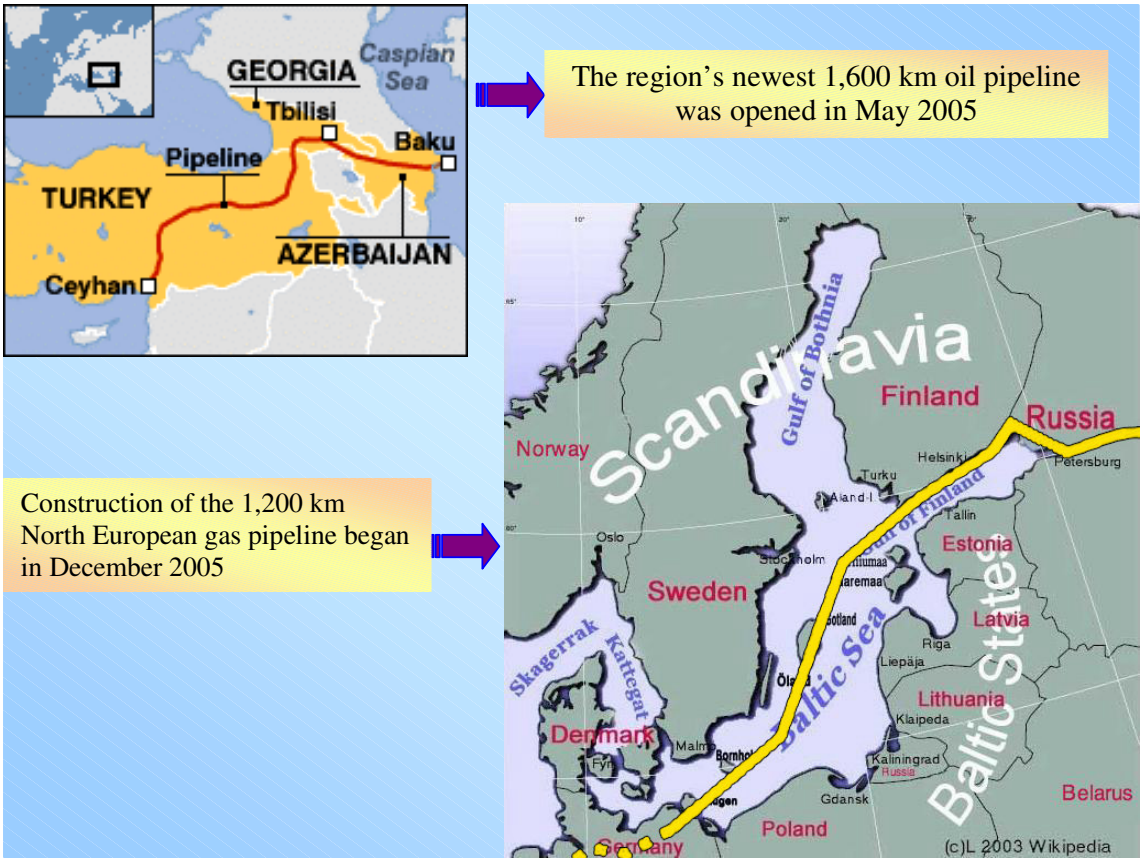

Figure 2. UNECE Pipeline networks developments

The most extensive pipeline network is for carriage of natural gas from the producer to local distribution networks. Gas transmission pipelines are buried underground and are necessarily routed through cities, and can come close to residential populations. The total length of European High Pressure networks was approximately 200,000 km in 2003, on the rise with respect to 1996 (~180,000 km) [2]. The length of onshore gas transmission and gathering pipelines in United States (US) remained practically constant since 1984 (~500,000 km). Besides European High Pressure network length, the total consumption of natural gas is also growing: in Europe in 2004 it increased by 3.3 % in comparison with 2003 (source: European Union of the Natural Gas Industry-EUROGAS). The gas pipeline network of Italy consists of approximately 33,000 Km natural gas pipelines. According to the resolution of the AEEG n. 120/01, the natural gas pipelines have been divided into two parts: the first belonging to the National Gas Pipeline Network, for a total of about 10,000 km and the second to the Regional Gas Pipeline Network, for the remaining pipelines. Taking into consideration the limitations imposed by importation, by the main national productions and by stocking, the function of Italian National Gas Pipeline Network is to transfer significant quantities of gas from the inlet points in the network to macro consumption areas. Instead, the principal function of the Regional Gas Pipeline Network is to move and distribute natural gas across well-defined territorial areas, typically on a regional level. The natural gas coming from abroad is inserted into the National Pipeline Network through 5 entry points corresponding to the interconnections with the methane import pipelines (from Russia, Algeria, Libya, Nord Europe –Norway &The Netherlands - and the LNG re-gasification plant). The exit points on the National Pipeline Network are 17 withdrawal areas and 3 interconnection points with international export pipelines (figure 3.).

Figure 3. National Gas Pipeline Network of Italy

Apart from natural gas, pipelines are a safe and efficient mode of transport for crude oil, petroleum products and other chemicals such as chlorine, ammonia, etc.. They are used both for short-distance transport (e.g. within a refinery or depot, or between neighbouring installations) and over long distances. There is an extended onshore network throughout the EU used for the carriage of crude oil and refined products including gasoline, kerosene, diesel and heavy fuel oils. On the base of the Oil Companies' European Organisation for Environment, Health and Safety (CONCAWE) data, the EU has an extensive network of onshore pipelines with a total length of nearly 40,000 km in 2004, compared with ~12,000 km in 1971 and ~30,000 in 2000 [3]. Moreover, there are approximately 10,000 km of chemical pipelines within the EU carrying a total of more than 150 hazardous materials among which ethylene and propylene are conveyed in the most of those networks. For comparison, the total length of liquid transmission pipelines in the United States remained practically constant during the 18-year period 1986 – 2003. The liquid transmission grid comprising oil and other hazardous material pipelines shows a variation between 245,000 and 258,000 km with an average length of ~ 250,000 km.

In comparison with other modes of transport (rail, road, maritime), if the pipelines are well planned, constructed, properly operated and maintained, the transport of dangerous substances through pipelines is quite safe and environmentally friendly. However, in case of accidents, they may cause grave damage to human health and safety and to environment, in particular to soil and water. In fact the effects of accidents involving pipelines can be very serious as shown by the Komi (Russian Federation) oil leakage in 1994 and the Ghislenghien (Belgium) gas explosion in 2004.

The European Gas Incident Group (EGIG) represents twelve major natural gas transmission network operators in the EU (Denmark, Spain, Belgium, Finland, France, Netherlands, Germany, Italy, UK, Switzerlan, Czech Republic and Portugal). The total length of the EGIG networks was estimated to be 122,168 km by the end of 2004. The natural gas incident records kept by EGIG database in the period 1970 – 2004, amount to a total of 1123 incidents with an average of 33.1 incidents per year. The overall incident frequency over the same period is 0.4 incidents per year per 1000 km pipeline, with an improvement approximately 25% in the last decade. For comparison, the natural gas incident records kept by US Department of Transport (US DOT) database in the 33-year period 1970 – 2002, amount to a total of ~7200 incidents (average 218.7 incidents per year). US Department of Transport reports incident statistics of natural gas pipeline operators that control transmission pipeline networks of total 500,000 km length. The overall incident frequency in the 33-year period 1970 – 2002 is 0.44 incidents per year per 1000 km. In the period 1986 – 2002, the overall incident frequency remained in some way constant at ~0.16 incidents per year per 1000 km and it has been improved only ~8% in the last decade [4, 5].

The cross-country oil pipeline performance records kept by CONCAWE database in the 31-year period 1971 – 2001, include to a total of 394 incidents with an average of 12.7 incidents per year. The overall incident frequency over the 30-year period 1971-2000 is 0.65 incidents per year per 1000 km pipeline, showing an improvement about 15% in the last decade. The incident records obtained in the US hazardous liquid pipeline grid can be compared with those in Europe (CONCAWE records). The hazardous liquid incident records kept by US Department of Transport database in the 33-year period 1970 – 2002 amount to a total of ~6960 incidents (average 217.6 incidents per year). US DOT reports incident statistics of hazardous liquid pipeline operators that control transmission pipeline networks of total 250,000 km length. The overall incident frequency in the 33-year period 1970 – 2002 is ~0.85 incidents per year per 1000 km and it has been worsen ~6% in the last decade[3, 5].

The accident data mainly derived from EGIG, CONCAWE and US Department of Transportation show the accident cause of pipeline incidents are typically classified into the following six generic categories:

1. external interference or third party activity;
2. corrosion;
3. construction defect and mechanical or material failure;
4. ground movement or natural hazards in general;
5. operational error or hot-tap by error;
6. other or unknown causes.

As it is shown in the figure 4. relative to gas pipeline accidents [4], external interference, mostly third party activity involving interference using machinery, has been recognised as a dominant failure mechanism both in gas and oil-industry pipelines. Corrosion is another major causative factor for incidents, and mostly attacks ageing pipelines.

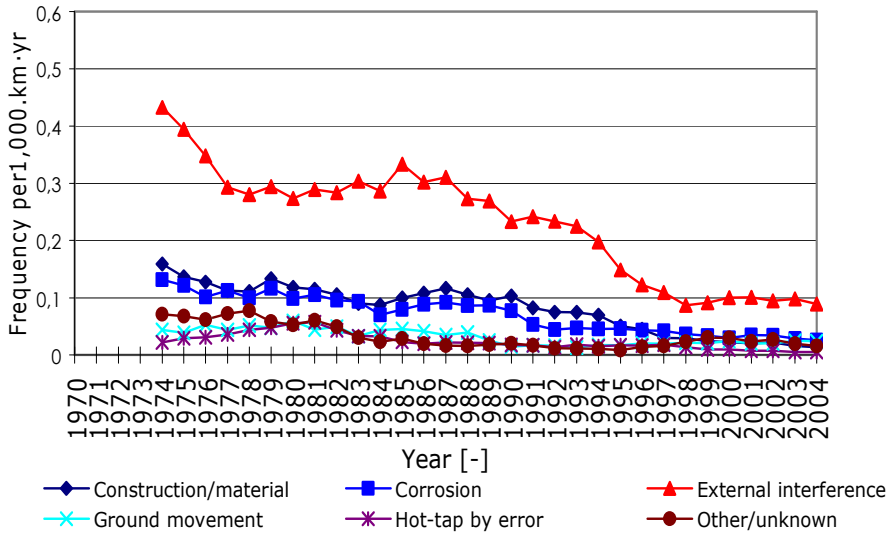

Figure 4. Gas pipeline accidents: primary failure frequencies per cause (5-years moving average)

In relation to the liquid pipeline networks, the main incident causes are construction and the material defects that are often connected with equipment linked with the pipeline.

Information on consequences of past incidents mostly refer to immediate effects on humans and possible environmental impact. In general, pipeline accidents occur less frequent but appear to have serious consequences similar, and sometimes more severe, to accidents in chemical plants and storages. Environmental damage such as contamination of soil and water and clean water and clean-up are mostly relative to oil spills, whereas health damage is mostly concerning to gas releases (4% of all cases, up to 25% for gas releases from larger diameter gas lines).

2. PIPELINE SAFETY MANAGEMENT

Taking into consideration the background relative to the pipeline accidents, above described, studies on pipeline hazards have been carried out at EU and UNECE level that show many differences in the pipeline safety management and important gaps in national legislation.

At EU level the pipelines are excluded from Seveso II Directive (Article 4 (d)). However, it is recognized that the transmission of dangerous substances through pipelines also has a potential to produce major accidents (Recital 13). Council and the European Parliament requested the Commission:

a.: to collect and evaluate information about existing mechanisms within the Community for regulating such activities

b.: to collect and evaluate information about the occurrence of relevant incidents.

To these aims, Commission had carried out:

- Questionnaire exercise (1996-97)
- OECD Workshop on Pipelines (Oslo, June 1996)

- Workshop on Pipelines (Berlin, October 1997)

- Study on "Regulatory Benchmark" on existing measures for the control of major-accident hazards arising from pipelines (1998-99)

- Revision and updating of the "Regulatory Benchmark" according to the responses from the Competent Authorities of 15 Member States (2003)

The conclusions from these activities at EU level on the prevention and control of accidents from pipelines conveying dangerous substances are similar to one on going at UNECE level to draw up guidelines/good practices for the safe transport of hazardous substances by pipeline. This task is under the auspices of two UNECE Conventions: the Convention on the Transboundary Effects of Industrial Accidents and the Convention on the Protection and Use of Transboundary Watercourses and International Lakes. The Parties to both Conventions gave the mandate of the joint expert group, a group established to consider issues of common concern to both Conventions, to provide safety guidelines/good practices for pipelines. The joint expert group established an open-ended steering group comprising experts on pipeline safety in order to assist in drawing up the guidelines/good practices for pipelines and to prepare two expert workshops at the end to provide the greatest possible input from all stakeholders. Experts from Institute for Atmospheric Pollution, nominated by Ministry for environment and land protection, have attended to the steering group activities, providing an useful contribution. The first workshop, held in Berlin on 8 and 9 June 2005 was on the prevention of water pollution due to pipeline accidents whilst the second one, which took place in the Netherlands on 8 and 9 March 2006, addressed the safety of gas transmission pipelines. These workshops allowed representatives of competent authorities and experts from private sectors, in particular operators of pipelines, and research institutions and non-governmental organizations to share information and experience on pipeline safety, including the existing legal framework and good practices to prevent, control and reduce the impact of pipeline failures and accidents. The participants of the workshops had the opportunity to comment on draft of the document "*UNECE safety guidelines/good practices for pipelines*", allowing to the steering group to come to the version of 10 April 2006 of the above mentioned document [1].

The data received within the activities carried out both at EU and UNECE level shown that there is a vast range of different experiences and solutions in addressing the issue of industrial safety including pipelines. Some countries are more advanced than others. In fact, some UNECE country regulations, such as the United States, contain requirements on technical rules comprising safety management system and prevention of third--party damage. Moreover the existence of the appropriate pipelines legislation in the United States contributes to know better accidents and their consequences. Although high standards relative to the pipeline regulations and safety performance have been reached by some countries, and even if the majority of operators recognize the importance of maintaining the integrity of their pipeline networks, in general there is a need for further improvements about the safety of pipeline operation in order to prevent incidents and to limit the accidental consequences for human health and the environment. The major gaps in national provisions are relative to:

1. safety management system (missing in most countries),

2. prevention of third--party damage,

3. accident reporting requirements,

4. information to the public,

5. emergency planning,

6. and use planning, etc

Against this setting, the "*UNECE safety guidelines/good practices for pipelines*" [1] are designed to give a minimum set of elements to reach a basic level of safety for pipelines and so to harmonize pipeline safety performance within the UNECE member countries. Also this last aspect is very important considering that most pipelines cross at least one border and that the effects of pipeline accidents are often transboundary and require an efficient, coordinated emergency response from two or more countries. The draft document drawn up by the steering group will be submitted, on behalf of the joint expert group, to the governing bodies of the Industrial Accidents Convention and the Water Convention for consideration and subsequent adoption at their fourth meetings (Rome, 15-17 November 2006 and Bonn, 20-22 November 2006, respectively).

Non-binding recommendations for pipeline safety already exist and the steering group also took into account these texts, in particular the "*Guiding Principles for Chemical Accidents Prevention, Preparedness and Response*" 2nd edition, 2003 [6].

The UNECE Guidelines contain recommendations to the UNECE member countries, competent authorities and pipeline operators mainly focus on the following topics:

a. Technical measures for pipeline safety,

b. Land-use planning,

c. Information Policy,

d. Risk Assessment on pipelines,

e. Emergency response and cooperation.

In consideration of the input received from authorities of UNECE member countries, pipeline operators and other experts, the steering, in carrying out its task, tried to take into account the fundamental differences between the handling, processing and storage of dangerous substances in fixed industrial installations and the transportation of dangerous substances in pipelines.

a. Technical measures for pipeline safety

The pipelines conveying hazardous substances should be designed, constructed, operated, maintained and monitored in a safe way so as to ensure the pipelines integrity and to prevent accidents and to mitigate the consequences of accidents. To these ends, when the pipeline operator designs, constructs and operates pipeline for transport of dangerous substances should use "*national and international codes, standards and guidelines, and where appropriate, internationally accepted company specifications*". It is to underline that there is no lack of quality standards or specifications (e.g. European Standards CEN 1594 Design/Construction/Operation and CEN/TC 234 Pipeline Integrity Management)

b. Land-use planning

The possible scenarios that the Authorities can encounter in the land use planning definition about the presence of pipelines are relative in particular to :

- the pipelines already existing (and their design can not be more changed);

- new pipelines can be constructed (and thus it is possible to define specific choices according to the land use).

In general, competent authorities should ensure that their land-use and/or other relevant policies and the procedures for implementation of the policies established take into account the objectives of preventing and limiting the effects of accidents, with particular regard to safety distances. In case of new pipelines, the route selection is a basic step in order to design and construct a pipeline safe also

taking into consideration its future operating life. The general criteria in the routing selection have to avoid or reduce to a minimum a transit in areas of particular natural or cultural interest, or which present construction difficulties or situations of potential risk for the pipeline such as inhabited areas, water catchment areas. Where construction pipeline is planned, it also should be avoided the presence of other facilities, proximity to road, railways, electric lines and other infrastructures. Land-use planning considerations should be taken into account also in assessments concerning proposals for new developments/building in the area of existing pipelines.

c. Information Policy

Pipeline operator should improve sharing of information on the safety of pipelines, the geographic position of pipelines, safety measures and the required behaviour in the event of an accident. Taking into account that external interference is known as the most important cause of pipeline accidents, in the case of digging activities by third parties the exchange of information about the geographic position of pipelines should be realized quickly to prevent third party damage to pipelines. In fact, effective communication and information are important both in the preventive actions and in facing up to possible anomalous situations. Obviously the communication and information policies assume different characteristics according to the stakeholders (authorities, public, landowners, suppliers and company employees) and the goals which are addressed to, but represent transversal and constant elements in the safety and environmental management policies.

The UNECE Guidelines underlines that "*Information should be provided to the public in accordance with relevant provisions of UNECE environmental Conventions. At the same time, security concerns should be taken into account. Security concerns are not within the scope of these guidelines*".

d. Risk Assessment on pipelines

The operators emphasized that risk analysis is only a possible method for identifying and assessing possible hazards, and that in Europe deterministic approaches are used with equivalent safety results.

So the guidelines recognize the principles of equivalence of deterministic and/or probabilistic approaches in evaluating pipeline integrity and impacts on human health and the environment. These principles are confirmed in the annex V with the possibility to use different evaluation approaches by combining the expressions "hazard assessment" and "risk assessment' in "hazard/risk assessment"'.

e. Emergency planning

The guidelines remark the need to get ready appropriate measures for limiting the consequences for human health and the environment in case of accidents. So, pipeline operators and authorities should establish, test, implement and regularly update respectively their internal emergency plans and external emergency plans.

Internal emergency planning should be part of the pipeline management systems which the operator should implement to guarantee high level of protection of human health and environment.

The pipeline operators underlined that too many are the variables and the uncertainties to be considered in systems of thousand kilometres long and that introducing rigid and specific procedures about some matters risk to make too rigid the emergency tool. With systems like pipelines every emergency intervention assumes generally specific characteristics and therefore flexibility should be the keystone of an effective emergency planning.

Finally, with respect to 'filling gaps' in the existing legal situation in the UNECE region, other important elements considered in the UNECE guidelines are systems of permits and inspections which competent authorities should carry out in order to ensure that pipeline operators meet requirements.

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