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Environmental Deviation Assessment, Record, Failure, Probability and Investment

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A major difficulty in establishing the program of action or devices to prevent the risk of incidents and accidents are the occupational and environmental records of deviations and its research into the causal connection. The proposed work aims to analyze deviations of the operation, process and maintenance of industrial facilities that impact on the environment. These deviations are observed and recorded to investigate the failure mode and recommending ways to mitigate its impact. The steps of this methodology are: (1) registration of deviations from routine (database); (2) the causal analysis and fault tree construction; (3) definition of the logical operator and calculation of probability; and (4) investment analysis to mitigate impacts. This technique was applied in the case of oil spill from machines in a chemical industry and environmental impacts. An understanding about the relation between deviations, causes, and top event allow quantifying the probability, set management actions, and/or designing technical devices economically viable.

1. Context

According to Ávila (2004), the losses in the industry of chemical processes occur due to ignorance of best practices, lack of skill, lack of systemic vision, uncontrolled process and lack of good social relationships. Based on Brazilian cultural scheme, the management system installed in the company values do not learn from success and failure, thus assigning the blame to the people involved in the crash. According to Dekker (2002) the investigation of human error has not advanced in Brazil, where it's fixed in the initial stage of analysis of human error. At this stage, the priority is to investigate the person responsible for the loss and not the failure to analyze the environment, interpreting the factors that affect the failure and learning in order to prevent future human errors and the resulting operational failures. Several techniques are been developed to risk analyzes based on human factors (Barroso, Avila and Quintella, 2011). Most of the failures and accidents are analyzed after its happening (Ávila, 2010) and cannot properly diagnose the possibility of future failure; regardless of being an accident, a fatality or a major leak. The industry investigates, at most, the lost-time accidents or incidents with high loss. The building of a good database about routine deviations allows the planning of a program to avoid wasting process, and then, designing devices to prevent the risk of incidents and accidents to happen, environmental and occupational ones.
The record of deviations and its investigation into the routine's causal relation increases the visibility of the processes' future and the occurrence of a probable top event. The chances to identify the root cause are the largest when studying deviations from routine.

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2. Aims

Establish method to build the database, investigate the causal relation using the fault tree, calculate the probability, and identify the investment required to the safeguards in relation to the consequences of occurrence of the top event or an accident under construction.

3. Methodology

The proposed work aims to analyze deviations of the operation, process, and maintenance of industrial facilities that impact on the environment. These deviations are observed and recorded to investigate the failure mode and recommending ways to mitigate its impact. The steps of this methodology as indicated in Figure 1: registrations of deviations from routine (database), construction of fault tree for causal analysis (Verley and Roberts, 1981), quantification of the probability from the definition of logical operators, and analysis investment to mitigate impacts.

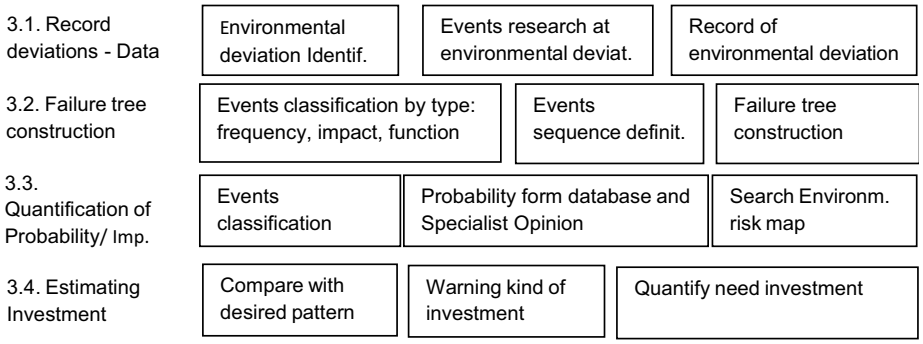

Figure 1: Environmental deviation Assessment: record, investigation, calculation and investment

3.1 Registry of environmental deviations

The industry needs to build a database of deviations and non-compliant events from routine data to its historical analysis, allowing quantitative analysis of any future failure. This record feeds the system environmental database of deviations and environmental events, facilitating the identification of root causes and discussion of the logical relation between these root causes and ultimate failure. It is important that the recording and analysis of data takes place in the shift team (Ávila, 2004, 2010) or by the company staff. An initial analysis is done for the validation of the deviation, ie, the fact is related to an existing problem. In the record of the deviation are informed: date, time, class, area, plant conditions, and weather conditions. A brief description of the process or activity facilitates the contextualization of the deviation and the suggestion of some environmental causes and immediate consequences. It is important to analyze the type of current control and the proposed new control measures or improvements. It is suggested a position of deviation in the fault tree for further analysis and confirmation. The deviation analysis through interviews and visits to the area and access to documents is recorded either in the auxiliary field as descriptive or photos / drawings on the back of the sheet. The steps to register the deviation are shown in Figure 2.

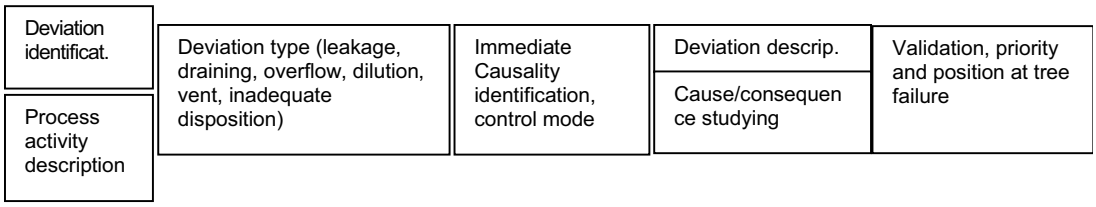

Figure 2: Steps to Environmental deviation Record

3.2 Failure Tree

In this stage, we intend to investigate the causal relation of the deviations identified in the registration step, looking for root causes. It is intended to establish a logical relation to direct (and, or) or indirect (influence) operators, among the primary causes, consequences and the event leading to the top of the fault tree construction.

The attempt to identify the top event and root cause related to these deviations enables the understanding of how the failure is built and allows us to suggest actions to prevent it from happening. In the record of the environmental deviation analysis at TECLIM's research projects, some secondary deviation are recorded and be labeled of region of causal event, intermediate event or top event. It is necessary to complete the investigation about the kind of relation between events or deviations (multiply the probabilities for dependent events and the sum probabilities for dependent events). Also, is important to identify events that have influence over others, but have no logical relations established.

The ongoing of this research, making registration deviation in fault tree, indicates that the environmental impact is considerable, based on the frequency or the gravity of the failure. It is important to go deeper in this study with new visits in the fields, interviews, and additional record of events, enriching the fault tree.

The fault tree's construction is an exercise to make it easier to choose ways to prevent similar failures. At the same time, aims to measure the strongest possibilities to reach for the top event. Industrial plants do not have enough resources for all safeguards or barriers raised in failure analysis. The choosing of what are the probable barriers is related to the greater chances of happen and the logical relations that induce to the top event. Another important factor to be considered is the investment costs to secure a barrier. These issues will be further detailed in the procedures for quantification of events or deviations to calculate the fault tree and also in the estimation procedure of risk investment map available as framed. The steps involved in building the fault tree are described in Table 1.

Table 1: Steps of failure tree construction

Review of deviation classificati on	Investigation of events or deviations: causes consequences	Failure tree Construction – logic sequence	Logic and subjective Operators	Analyze/ review barriers/ actions	Publish and validate failure tree

In Figure 3 are shown the first two phases of the investigation of environmental deviations: (1) observation in the field to record the deviations in the database, and (2) development of the causal relation of events, indicating the probable causes and the top event.

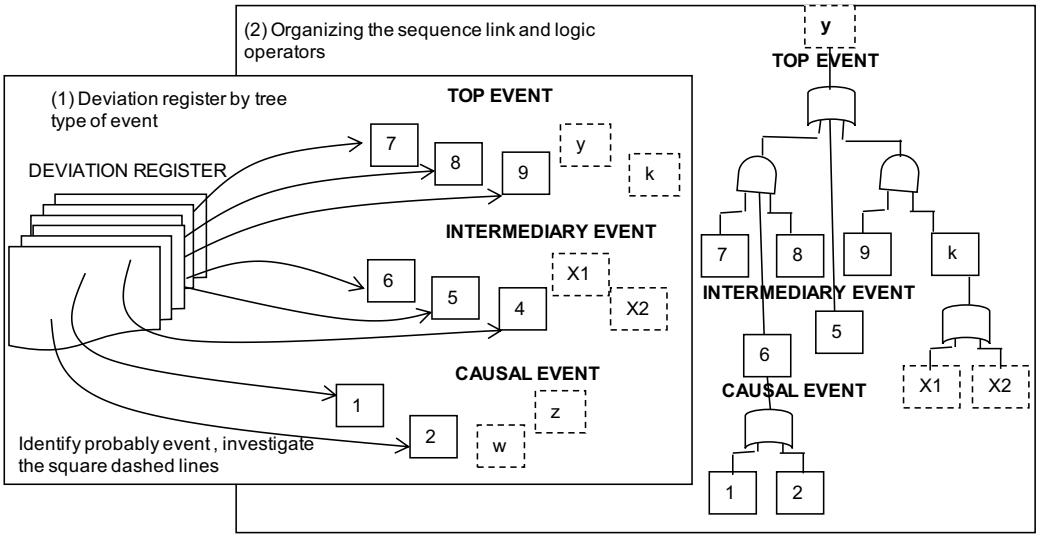

Figure 3: Schemes about the Record collection and the construction of causal connections

3.3 Probability Calculations

The calculation of the probability analyzes the urgency of investment in the deviations, indicating the frequency with which they occur and their subsequent chain of events. In Figure 4, the top event is represented by T and the causes that initiate the event are A, B, F, G. The causes F, G and D (intermediate event) are influenced by the environmental situation in W in the ratio from 0.2 to 5 %. If the logical operator is dependent, the odds are multiplied. If not, they'd add up.

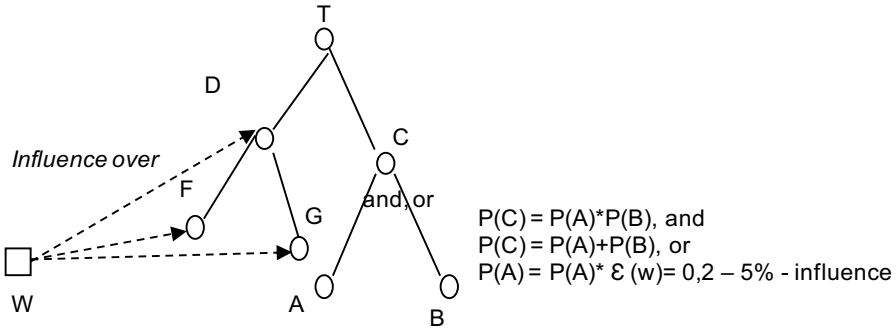

Figure 4: Equations for the events' probabilities

3.4 Investment Assessment

The third stage of the investigation of environmental deviation analysis is the investment analysis, which is linked to the fault tree top events in the investigation and probable connections between events. The investment analysis investigates the environmental risks first, making an association with each option related in the fault tree and theirs required investment, level of contribution (return period and net present flow) and the level of satisfaction desired by the company.

Table 2: Schemes about investment and environmental risks

Analysis of conections between events	Analysis of risks associated with each possibility	Analysis of the Company`s desired environmental standards	Estimate financial return and investment of each possibility	Relate the options to the financial study and the Company`s environmental standards

4. Case: Record and Failure Tree

The application of environmental deviation analysis was applied in a section of the factory responsible for the storage and loading of the final product, where the effluent from washing the area contained high concentrations of oil, being constant during the plant maintenance periods. The incident log was listed in Table 3, containing the deviations in the plant area analyzed regarding the separation equipment, the deviations in the effluent and the source of the oil spill.

Table 3: Record and preliminary assessment of deviation to oil case from dynamic equipments

Researcher (es):		------					
Date: 03 / 06 / 2011		Time: 10 :30 h - 12 : 00 h		Group: B			Area: ----
Plant conditions:		☐ Mainten.	☐ Starting	■ on operation	Cap. - %		Obs:
Weather conditions:		☐ No rain	☐ recent rain	■ recurrent rain	Obs:-		
	Process description	Type of deviation	Deviation's consequences	Deviation's causes	Current control measures	Improvements	Event
1	Link between oil-water and separator (SN)	Draining	Uncontaminated effluent system (SN)	(a) Project	(a) Deviation's investing.; (b) New projects.	(a)Removal of the link; (b)cease S	Top

With a record of deviations, we observed the oil spill in the compression systems of the plant as the cause. This contaminated oil leaked through the factory floor, and even the chains of the final product, overloading separation systems and reducing product quality and efficiency of heat exchangers. With the construction of fault tree, we analyze the compression system, its operation, its components, and the overhead of the effluent. As a final consequence, the overloaded sewage flee to the specifications of the treatment station, resulting in fines and damaging the company image.
The analysis of the material loss is estimated at 250 L/month of oil, which is reset to the compression system, equivalent to 3 000 L/year oil defendant. With the investigation of the compression system, it is recommended to maintain the mist separator, which is inefficient and causes contamination of the process stream. In order to mitigate the loss of oil to the effluent, it is suggested to use a vacuum for separation and reuse of the spilled oil.
In the case of Figure 5 is suggested a fault tree with their impacts and barriers. Showing: corrective (mitigation) and preventive action. The events are related to stop CO_2 compressor, leakage due to back pressure, generation of effluent from the synthesis reactor, the effluent non-standard, fine and negative image. Among the environments that influence the root cause or initiator event are: inadequate organizational culture causing undue maintenance contracts and improper writing of critical tasks.

5. Results

The method's applying in the registration and causality phases allows the building of a management program to improve the environmental impacts of the shift routine. This paper presents a case of practice in the chemical industry, demonstrating the importance of building a database of environmental deviation, which has a good systemic view, with some detail about the processes, and as a result of tying a causal relation by constructing the fault tree based on deviations from the routine.
The utilization of the environmental deviation analysis method has several benefits for the company:

- The method for preparing technical analysis of failure that causes environmental impact;
- Training database of environmental deviations, root-cause and top events;
- The researches indicates preventive actions to avoid the occurrence of top event;
- If it matches the estimated range of probability and cost, facilitates decision making for environmental risk management routine, similar from occupational risk management (Souza, 1995);
- Increases the perception of risk in growth, leading the team to take preventative action if it's noticed a lot going on environmental deviations;
- Performing photographic record of events and research improves decision-making process, due to the establishment of a causal connection between the events;

6. Conclusion and recommendations

This method presents robustness when it is developed and accepted in routine to facilitate the investigation of the consequences of failure with chains in the environmental area. It could be considered the training of analysts a method to investigate the failure. The database must be automatized and a large group of technicians must be trained to analyze the routine considering environment deviations.
With the identification of the deviations and the causal relationship built, the probability of the top event happen is lowered. If there are more training to avoid deviations, the incidents also would be inhibited. To apply this type of analysis is important to develop cases of application for specific areas and then expand training for staff in general.

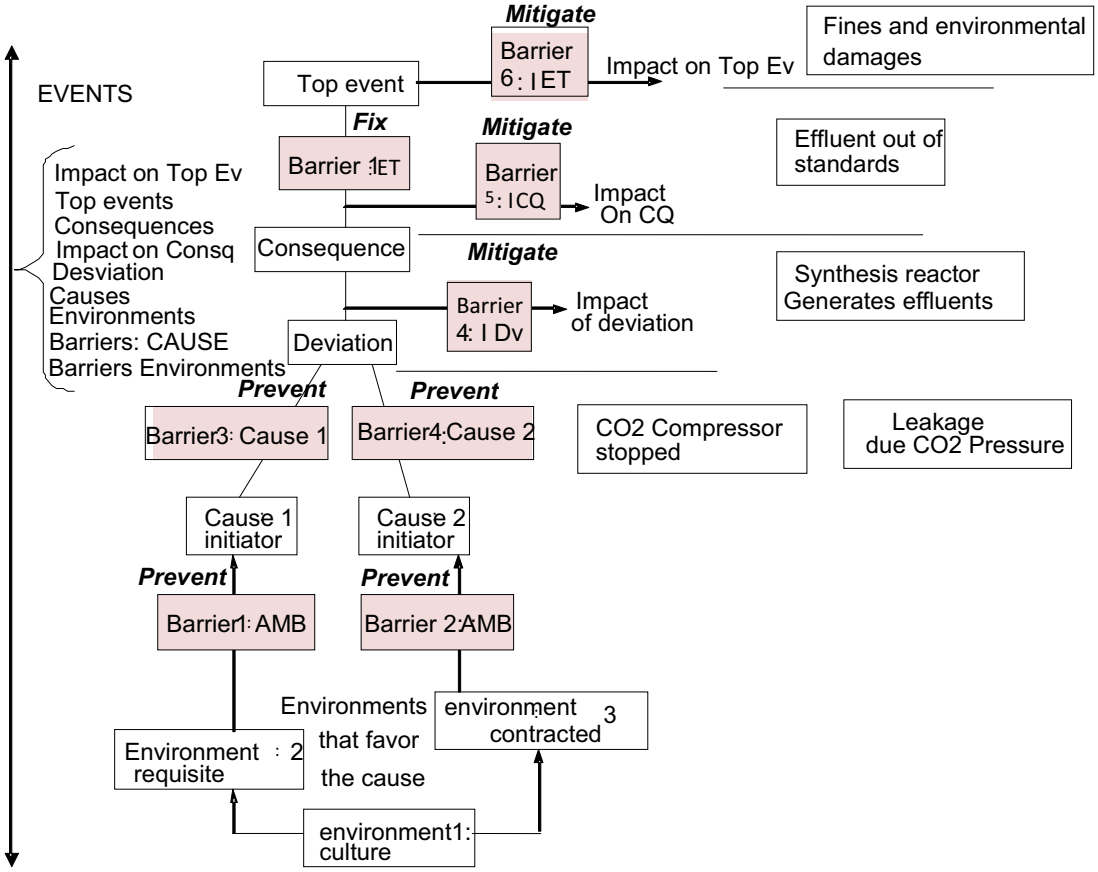

Figure 5: Construction of failure tree with suggestion of safeguards

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