Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

STRIVE

Report Series No.125

Supporting the Concept of Early Warning Analysis – SCEWA

STRIVE

Environmental Protection Agency Programme

2007-2013

SSTI Strategy for Science, Technology and Innovation

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

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- Office of Environmental Enforcement
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- Office of Communications and Corporate Services

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EPA STRIVE Programme 2007–2013

Supporting the Concept of Early Warning Analysis – SCEWA

(2007-DRP-2 -S5)

STRIVE Report

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ACKNOWLEDGMENTS

This project (Grant No. 2007-DRP-2-S5) was funded by the Irish Environmental Protection Agency (EPA), under the Science, Technology, Research and Innovation for the Environment (STRIVE) Programme 2007–2013. The programme is financed by the Irish Government under the National Development Plan 2007–2013. The author wishes to acknowledge the support of the EPA and of the Cork Constraint Computation Centre in the development of this report. The author also wants to convey special thanks to John Feehan from the EPA Office of Environmental Enforcement for his invaluable help on various occasions and for sharing his knowledge and experience with the SCEWA team on various aspects of this project.

The SCEWA team members would like to thank Cait Gleeson, Senior Executive Scientist and Donal Brennan, Senior Engineer in Limerick County Council for their co-operation, help and feedback; Dr. Ian Pitt from UCC for his support and guidance; all members of the steering committee of the project for their invaluable comments and feedback, as well as Dr. Brian Donlon from the EPA for his constructive comments and advice. Finally, they would like to thank Mr. Andrew Curtin of HSE in Limerick and Mr. Pat Massey from the Newcastlewest Water Treatment Plan in Limerick, as well as Mr. Pat Murphy and the staff of Lee Road Water Treatment Plant in Cork for their co-operation in the context of this project.

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EPA STRIVE PROGRAMME 2007-2013

Published by the Environmental Protection Agency, Ireland

PRINTED ON RECYCLED PAPER

ISBN: 978-1-84095-538-5

Table of Contents

Executive Summary

Background

On January 2008, the Irish Environmental Protection Agency (EPA) funded, under the DERP grant scheme, the research project "Supporting the Concept of Early Warning Analysis" (SCEWA). This project emerged from the need to study and address one real-world problem and one research problem. The real-world problem stemmed from the need for organisations to be proactive to accidents and failures in complex socio-technical systems. The research problem originated from the multiple facets, which the early warning sign concept receives in the relevant literature. This, in turn, created the need to: a) Study various opinions and perspectives on the early warning sign concept; b) Deliver novel approaches for the identification and justification of early warning signs to accidents; c) Design and develop tools that support organisations to be proactive to accidents.

The ultimate goal of the SCEWA project was to support organisations and state agencies in providing early warning services to accidents and failures. Setting such a goal was quite challenging when the project begun because the study of early warnings at that time had not attracted the attention of many researchers, as it has today.

Objectives

There were two key objectives to the SCEWA project:

1. Understand and “put into order” existing views and perspectives about the early warning sign concept. The goals associated with this objective were to: a) Introduce a novel approach for the identification and justification of early warning signs to accidents; b) Create graphical modelling languages using fundamental concepts, components, relations and constraints of the novel approach for the identification and justification of early warning signs, and incorporate these into a prototype open source software editor.

2. Design and develop, based on state-of-the-art Web technologies, a working prototype early warning information fusion system for safety issues in drinking water treatment plants. The goal associated to this objective was to make use of the Software as a Service (SaaS) deployment model, which allows many users to use one instance of a software application through their Web browser.

To achieve these objectives, the SCEWA team used theories, methods, tools and techniques from a number of disciplines, such as systems theory and cybernetics, systems safety engineering and water purification approaches, artificial intelligence and domain specific modelling, cloud computing and multi-tenant databases.

Key Outputs

The most important outputs of the SCEWA project are:

1) A working prototype SaaS-based system, which was designed and developed to receive early warning signs and information on safety issues relating to drinking water treatment plants, and disseminate these to appropriate recipients. The system receives early warning information from sensors and key stakeholders like, for example, the caretakers of the plants, senior engineers and environmental inspectors. It then assesses the safety level of the drinking water treatment plants and disseminates warnings and alerts to the appropriate recipients. The novel SaaS-based early warning information fusion system was tested in the Newcastlewest Water Treatment Plant in County Limerick. The system was able to facilitate the reporting of early warnings which were perceived by the agents and stakeholders responsible for its safety, such as the caretaker of the plant, the senior engineer of the water service authority, the environmental inspectors, the public health officers and the laboratory technicians, who conducted periodic testing on the water supply. In addition, it was able to disseminate the reported early warnings to the appropriate recipients via emails, as

well as via their dedicated user interfaces through special markers and other widgets.

2) A comprehensive procedure for the identification and justification of early warning signs to accidents in man-made systems. This procedure is called Early Warning Sign Analysis based on the STPA (EWaSAP). As its name suggests, it is based on the Systems Theoretic Process Analysis (STPA), which is a new hazard analysis technique based on the theoretical accident causality model called System-Theoretic Accident Model and Processes introduced by Prof. Nancy Leveson of MIT. STPA is a rigorous method for examining the control loops in the safety control structure of a system to find potential flaws and the potential for (and causes of) inadequate control. However, a limitation of STPA is that it lacks steps that aim to identify those perceivable signs which indicate: (a) the presence of flaws in the process control loops of the system; (b) the violation of its designing assumptions during the phase of operations. This limitation is addressed by EWaSAP, which adds three extra steps to STPA’s four-step approach. The steps of STPA and EWaSAP are repeated in a recursive manner, as the study for the identification of early warning signs to accidents in a critical process enters into more detailed levels.

EWaSAP was applied to the chlorination process of a water treatment works in the city of Cork, in order to see if management had incorporated some of the early warning signs identified with EWaSAP into the current management systems in place at the works. The application was successful because EWaSAP was able to identify a total of 43 warning signs, 37 of which were new and six were confirmed to exist already. In essence, with EWaSAP, it was possible to identify the early warning signs that existed in the Safety Management System (SMS) and to identify many more.

Apart from creating EWaSAP, the SCEWA team transformed the concepts and relations of EWaSAP into graphical domain specific modelling languages. Furthermore, the graphical modelling languages were incorporated into an open source software editor that can be used by analysts to identify, collect, manage and analyse early warning signs to accidents and failures in various critical infrastructures and safety critical systems. The editor is capable of generating executable computer code from the graphical models, which may be incorporated into the controller's knowledge base of early warning systems.

1. Introduction

Keeping critical infrastructures, such as Drinking Water Treatment Plants (DWTP), transportation, power generation and communications systems, safe is a complex task. The effective collection, as well as the aggregation and dissemination of early warning information among stakeholders that form the SMS responsible for the provision of safety in these critical infrastructures, are only a few of the challenges that needed to be addressed.

A characteristic example of a complex SMS is the system responsible for the provision of safe drinking water to the general public in the Republic of Ireland. As Figure 1 shows, among the key components of this system are the DWTPs, which are engineering facilities responsible for the purification of the water to appropriate quality standards. Additional elements of the SMS are the Water Service Authorities (WSA) and state agencies, such as the Environment Protection Agency (EPA) and the Health Service Executive (HSE). The WSA are special departments within the local authorities of Ireland, which are responsible for the day-to-day operation of DWTPs and, among other responsibilities, should notify the EPA, whenever a drinking water quality parameter exceeds its acceptable quality threshold value and inform them of potential mitigation actions, and consult with the HSE on the potential health consequence of such an exceedance. The EPA regulates the WSA and conducts audits at the DWTPs. In essence, DWTPs are elements of a complex socio-technical SMS and, thus, their performance and safety is affected by many factors, including environmental disturbances and technical failures, as well as, by dysfunctional interactions among elements of the SMS.

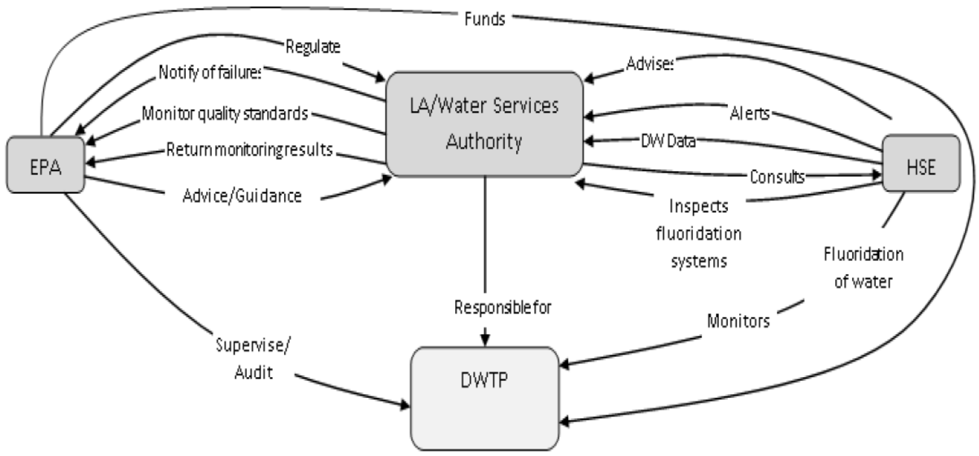


Figure 1. The Key Elements of the SMS for the Provision of Drinking Water in Ireland

The SMS described above presents challenges to ensure that the drinking water standards set by the European Union are complied with. For instance, it was reported that a third of all water supplies in the country is on the list of identified vulnerable water supplies, which is known as the Remedial Action List (RAL) (Irish Environmental Protection Agency, 2011). In 2010 alone, 43 boil water notices and seven water restrictions notices (serving approximately 65,000 persons) were put in place by 16 WSA. The most notable consequences of not supplying safe drinking water to the general public are those related to public health. For example, the most serious drinking water outbreak recorded to date in the Republic of Ireland is the cryptosporidium outbreak on Lough Corrib, County Galway that occurred in March 2007, which affected water quality in the city of Galway. More than 200 cases of people with confirmed cryptosporidiosis were reported at that time.

One reason for the under-performance of this SMS is that a relatively small number of DWTPs are equipped with real-time sensors capable of detecting the presence of harmful agents in the water. Private and HSE-owned laboratories periodically conduct analyses of water samples taken from different DWTPs. However, the results of laboratory tests cannot be delivered immediately to decision-makers, due to the required time needed in order to analyse the samples.

Unfortunately, the alerts from sensors and laboratory tests usually reveal symptoms (i.e. that a drinking water contamination event has occurred) that emerge from a dysfunctional SMS. Ideally, warnings that indicate in a timely manner, the presence of, but most importantly, the "concurrency" of, a complicated set of contributing factors that together may turn a drinking water contamination scenario into a reality, must be accessible by those who have the power to act in order to avoid the worst case scenarios. These warnings may be perceived by agents that belong in many, if not in all, levels of the SMS and not just by agents at the operational level of the DWTP. Thus, mechanisms and systems that aim to enhance the collection and aggregation of early warning signs, which are perceived by either humans and/or automated agents located in different hierarchical levels of the SMS and their dissemination to the proper stakeholders, are important tools for a proactive risk management. Such tools need to combine data from multiple sources, aggregate the data and present them properly, in order to support and enhance the awareness of decision-makers about the safety levels of DWTPs.

Another challenge for any agent within a complex SMS is to maintain its ability to perceive the early warning signs of accidents and to justify these to the appropriate decision-makers. Indeed, the investigations of many accidents revealed that, in many cases, the early warnings were present but none of them was perceived and/or comprehended by the agents of the SMS. There were accidents also, where the early warning signs were perceived and reported but these reports did not receive the proper level of attentions by those who had the power to act in a timely manner to address the problems. Thus, there is a need to provide a comprehensive method where it would be possible for the agents of a SMS to: (a) identify as many early warning signs to accidents as possible and (b) enhance their attempt to justify that the data which they perceived are truly early warnings (i.e. help them to clearly identify the relations between the data which they perceived, with the causal factors to accidents).

Among the deliverables of the SCEWA project are novel approaches and tools that, all together, attempt to address the important challenges described above.

The two key deliverables of this project are:

1. **A working prototype SaaS-based early warning information fusion system** for safety issues in DWTPs that; (a) facilitates various agents, located in different hierarchical levels in the SMS responsible for the provision of safe drinking water to the public of the Republic of Ireland, to report perceivable early warnings; (b) assesses the safety level of DWTPs; (c) disseminates warnings and alerts to all relevant stakeholders.

2. **A novel approach for the identification and justification of early warning signs to accidents**. This approach incorporates a widely-used hazard analysis technique that is based on systems theory and creates models of accident scenarios for complex socio-technical systems. The novel approach adds extra steps into the hazard analysis process, in order to guide analysts to identify those perceivable signs which indicate: (a) the presence of flaws in the process control loops of the system; (b) the violation of its design assumptions during the phase of operations.

These key research outputs will be described in detail in the following sections. In addition, the domain specific graphical modelling languages, which represent the concepts, relations and constraints of the EWaSAP approach, will be presented, together with some features of their prototype software editor.

2. A SaaS-based Early Warning Information Fusion System

2.1 SaaS

The increasing popularity of the Web has paved the way for a new breed of software, characterised by the fact that both the ownership and the maintenance of the software are outsourced by the service provider and not by the user, who now does not need to install it into his computer. With the new model, the software features are provided to end-users as services and are accessed via a Web browser. In essence, the software runs from a remote server, while the users can access and make use of its features via a Web browser. This category of software is named in the literature as Software as a Service or SaaS, on-demand software or subscription software (Turner et al., 2003).

One important technology necessary to build and deploy a SaaS application is known as multi-tenancy. A Web application is said to be multi-tenant if it allows its users to share the same hardware resources, by providing only a single instance of the application and its underlying database that is shared between all users. Throughout the execution of the application, users are allowed to customise the application to meet their needs. Finally, the mechanism behind multi-tenancy should be completely transparent to users. These users are also known as tenants (Bezemer and Zaidman, 2010). A tenant is the organisational entity that uses a multi-tenant application on-demand. A tenant usually consists of a plethora of end-users which are part of the organisation (Bezemer and Zaidman 2010).

For example, referring to the problem of DWTPs safety in the Republic of Ireland, the EPA, HSE, WSAs and DWTPs may be represented as different tenants within a SaaS-based early warning information fusion system. Each tenant can have different roles. For instance, the EPA may be represented within the SaaS system through two roles: the administrator and the inspector. The administrator is responsible for the creation of new users and DWTPs in the system and he/she may perform the following tasks: add users; update their personal data; remove them from the database; add new DWTPs into the system; and assign EPA Inspectors and HSE Health Officers to a newly defined DWTP. On the other hand, the EPA Inspector, due to their responsibilities as an agent of the SMS, will be free to interact with the RAL and see the changes of the hazard levels of each DWTP with time in a graphical representation.

The HSE may be represented within the SaaS-based early warning information fusion system through two roles: namely the HSE laboratory technician and the health officer. The laboratory technician is responsible for carrying sample results of the water and publishing them. These results will need to be validated by the HSE Health Officer before being made public.

The SaaS model enables the tenants of the system to use the same instance of the early warning fusion software without installing it into their computers. For such a complex problem, this feature is of importance because, among other things, it makes the early warning software easily accessible to all stakeholders, regardless of them being scattered throughout the country in different geographical locations.

2.2 Requirements

The high level requirements of the working prototype early warning information fusion system are presented below.

The system should be accessible to all stakeholders of the SMS, who are scattered throughout Ireland, and it should:

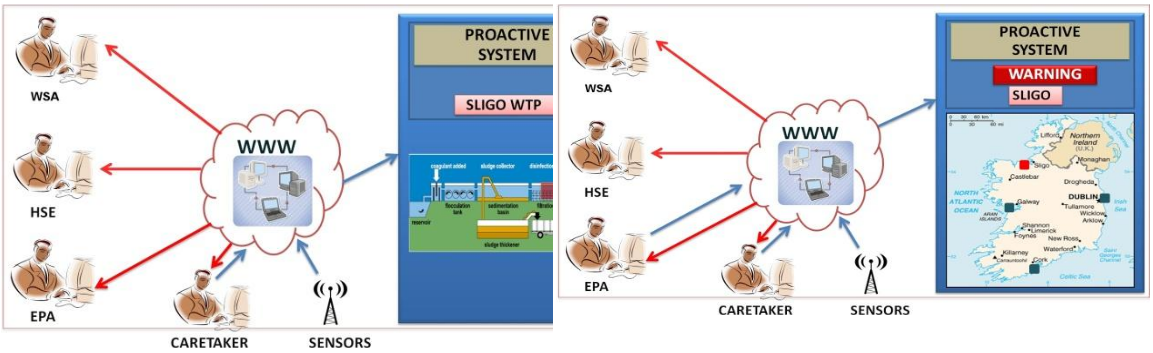
- make accessible to each stakeholder, important and relevant early warning information;
- allow the “definition” of new DWTPs into the system;
- allow users/domain experts to model and represent possible accident scenarios and enable them to update the represented knowledge relating to the contributing factors of accidents and to their associated early warnings;

- provide an estimation of the likelihood of an accident occurring in DWTPs, based on reported evidences and/or early warning signs;
- notify stakeholders by email or text messages when receiving important early warning information and/or when the assessed likelihood of an accident occurring exceeds its threshold value;
- allow as input real-time sensor data, as well as allow updates of the status of the components of the DWTP by their personnel;
- allow users to report conditions and safety-related issues that are not ordinary (i.e. emerging issues).

The objective was to design and develop a SaaS-based system where the caretakers of the DWTP, the EPA, HSE and WSA personnel will all have access via dedicated Web interfaces to the same software application, in order to report, disseminate and retrieve early warning information and alerts related to DWTPs safety issues.

Specifically, referring to Figure 2 (a), the caretaker of a DWTP will be able to log onto the SaaS-based early warning information fusion system (represented in Figure 2 (a) with the letters “WWW”). The system will recognise him/her as the caretaker of a specific DWTP and it will display their dedicated view, which they can use to report any perceived early warning information and emerging issues relating to one or more potential accident scenarios. The system will be able to collect near real-time sensor data from the sensors of the DWTP. If the assessed likelihood of an accident occurring, given the warnings provided by the caretaker and the sensors, exceeds a predefined threshold, then it will dispatch early warning messages to the associated EPA, HSE and WSA personnel (red arrows).

In addition, the EPA Inspector, or the HSE Health Officers, or the Senior Engineers of the WSA, as Figure 2 (b) shows, can log onto the SaaS-based system. The system will recognise them as personnel of the state agencies, or of the WSA, and it will display to them a view which will be appropriate to their role. The view of each role may have different features and functionalities depending on the responsibilities assigned to each role. For example, some functionalities available to the EPA Inspector’s view, such as the inclusion of a DWTP onto the RAL, may not be available to the Health Officers of the HSE. Through their view, each user can report the perceivable early warning signs like, for instance, in the case of the EPA Inspector, any warnings signs identified through a periodic audit in a DWTP, and they can see and browse the early warning information which was distributed by other stakeholders.



a) (b)

Figure 2. Two Use Cases of the SaaS-Based Early Warning Information Fusion System

2.3 Architecture

The architecture of the SaaS-based early warning information fusion system follows a layered model containing, as shown in Figure 3, the presentation, the business logic, the security, and the multi-tenant database layers. The presentation layer contains the following modules: a Hazard Visualisation module to visualise the hazard levels over a period of time; the View Switcher module which is responsible to render the appropriate view given the currently connected user; and the Web-based Editor module which enables the safety analysts to represent potential hazardous scenarios for each DWTP in the system with the use of an online Bayesian belief network-based hazard analysis editor.

The security layer contains sub-modules that were created to deal with potential security vulnerabilities such as eavesdropping acts, SQL injections and Cross-site Scripting Attacks. The business logic layer contains the Validator; the AI Engine; and the Warning and Alert Dispatcher modules. The Validator ensures that the work flow of the application is strictly followed by users. This is achieved by defining a set of rules that must be met by the users during the interaction with the objects of the application. The AI module aims at computing the hazard levels, giving a set of input data received from the users of system and from the sensors. The reasoning engine provides a wrapper around the actual computational model. The reasoning is executed based on Bayesian belief network technology. The Warning and Alert Dispatcher component is responsible for dispatching warnings in certain situations. For example, when the resulting hazard level has exceeded its threshold, this component is engaged in order to dispatch the warning messages to the stakeholders associated with the DWTP.

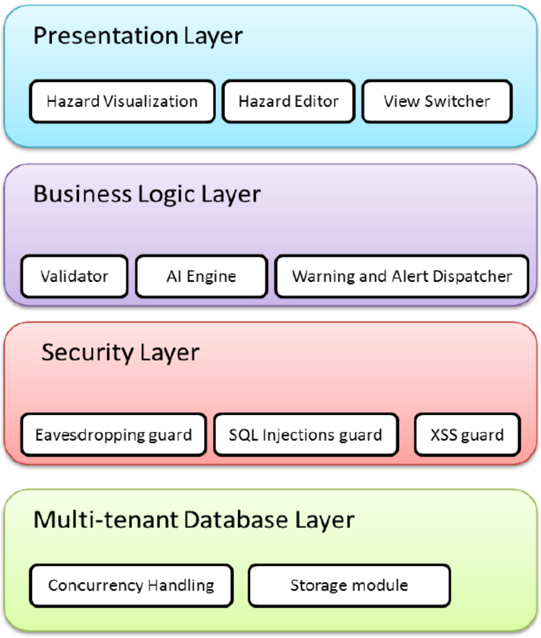


Figure 3. System Architecture

2.4 A Structured Walkthrough

A structured walkthrough of a use case scenario is presented below.

In this scenario:

1. the Caretaker, through his dedicated view reports an emerging issue;
2. the Senior Engineer receives the emerging issue and validates/approves it as an issue that needs to be transmitted to the state agencies (i.e. higher to the hierarchy);
3. the EPA Inspector and the HSE Health Officer become aware of the emerging issue;
4. the HSE Health Officer advises the Senior Engineer to issue a boil water notice;
5. the Senior Engineer accepts the advice from the HSE Health Officer and enforces the notice;
6. the marker representing the DWTP on the map, which is available in the user interface of the system, changes its colour from green to red indicating that its status has changed.

2.4.1 *Caretaker's View*

After logging onto the system, the Caretaker can see on his monitor an interface similar to the one shown in Figure 4. This view allows him to enter any predefined/sound warning signs and any emerging issues or weak warning signs that have been perceived by him. At the left hand side of his view, is a table that contains the sound early warning signs, that is, the signs that have been identified after implementing a hazard analysis approach. At the right hand side, a text box is available, where the user can specify any perceived emerging issue related to the DWTP safety. In this walkthrough scenario, the Caretaker reports the presence of e-coli in a routine sample test of the water entering the DWTP.

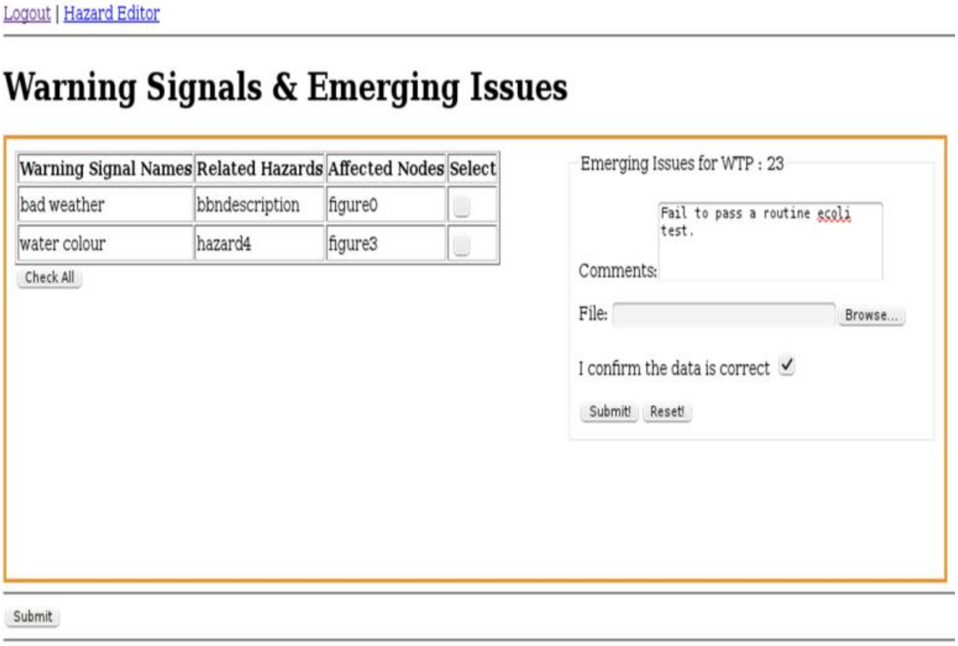


Figure 4. Aspect of the Caretaker's View

2.4.2 *The WSA Senior Engineer's View*

Figure 5 depicts a snapshot of the WSA Senior Engineer's view. The map in the middle of the view shows the area served by the WSA. The markers on the map indicate the DWTP managed by the WSA. Each marker contains information relating to the DWTP. At the left hand side, there are boxes containing widgets that allow a Senior Engineer to apply a number of actions, such as lift a restriction and/or a boil water notice. At the top right corner, there is a button with the label "emerging issues" that displays the emerging issues which have been submitted by the caretakers of the DWTPs that belong to the jurisdiction of the WSA. Figure 6, for example, shows a pop-up window that contains the emerging issue which was reported by the Caretaker in this use case scenario. If the Senior Engineer presses the "update" link in the pop-up window, the emerging issue is deemed by him as important and therefore it will be automatically visible to the EPA Inspectors and to the HSE Health Officers. If, however, the Senior Engineer considers the emerging issue as not being important, then he/she can "hide" it by pressing the "hide link".

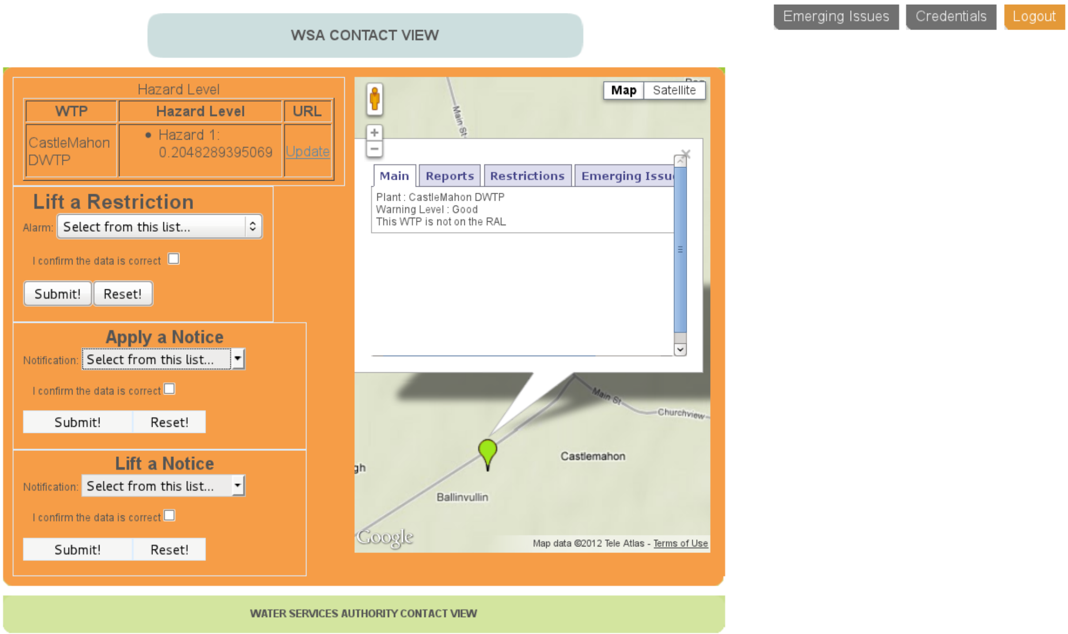


Figure 5. The Senior Engineer's View

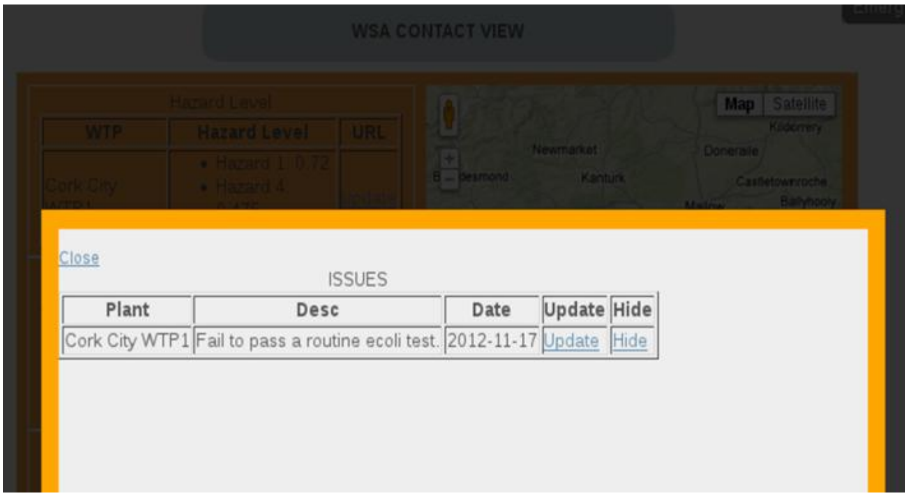


Figure 6. A Pop-Up Window with the Reported Emerging Issues

2.4.3 *The HSE Health Officer's View*

After receiving the emerging issue, which was deemed as important by the Senior Engineer, the HSE Health Officer can use the SaaS-based system to "formally" advise the Senior Engineer to issue a water boil notice. The HSE Health Officer's view is depicted in Figure 7. On the left hand side, there is a map and the markers on this map indicate the DWTPs. On the right hand side, there are boxes with widgets that a health officer can use to complete some tasks. In this walkthrough scenario, the health officers uses the widgets on the "Report and Incident" box to "formally" send an advice for a boil water notice to the Senior Engineer of the WSA. As result, the Senior Engineer and the EPA Inspector will receive his advice. Up to now, the warning level for the DWTP is in the "Good" level because, as per the regulations that govern this case, in order to change the warning level to a different level the Senior Engineer must firstly accept the advice provided by the Health Officer. Nonetheless, with the SaaS-based system presented herein, all key stakeholders are aware of the information which has been exchanged.

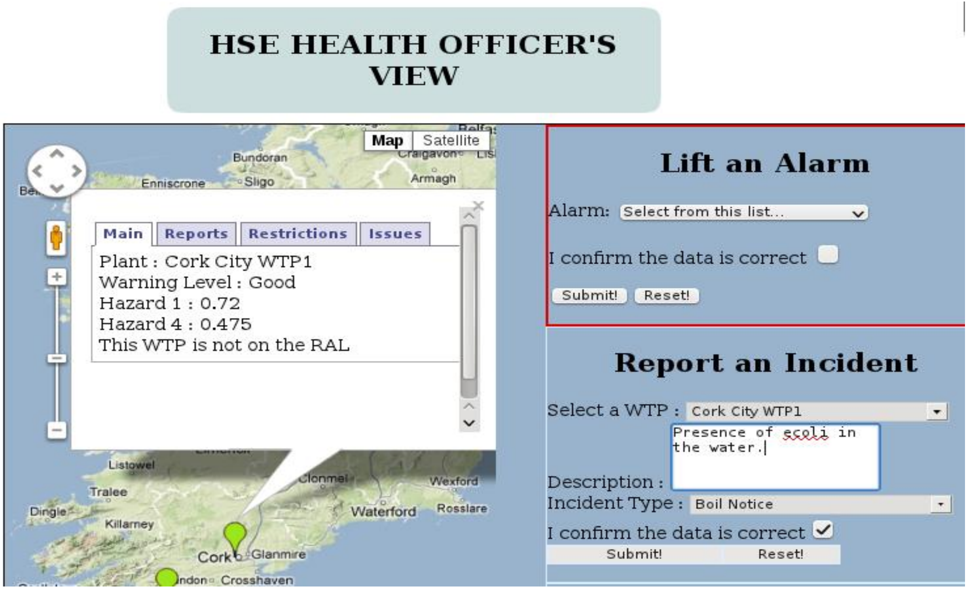


Figure 7. The Health Officer's View

2.4.4 *Change of the Warning Level*

In this walkthrough scenario, the Senior Engineer has accepted the advice given by the Health Officer, by applying a boil water notice using the widgets located in his view inside the box entitled "Apply a Notice". As result, the SaaS-based system has dispatched emails with a warning message to all stakeholders and has changed the warning level of the DWTP from "good" to "poor" in all views. This change can be recognised visually by every user via the marker that represents the DWTP in the map, which, as shown in Figure 8, has changed from green to red with an exclamation mark.

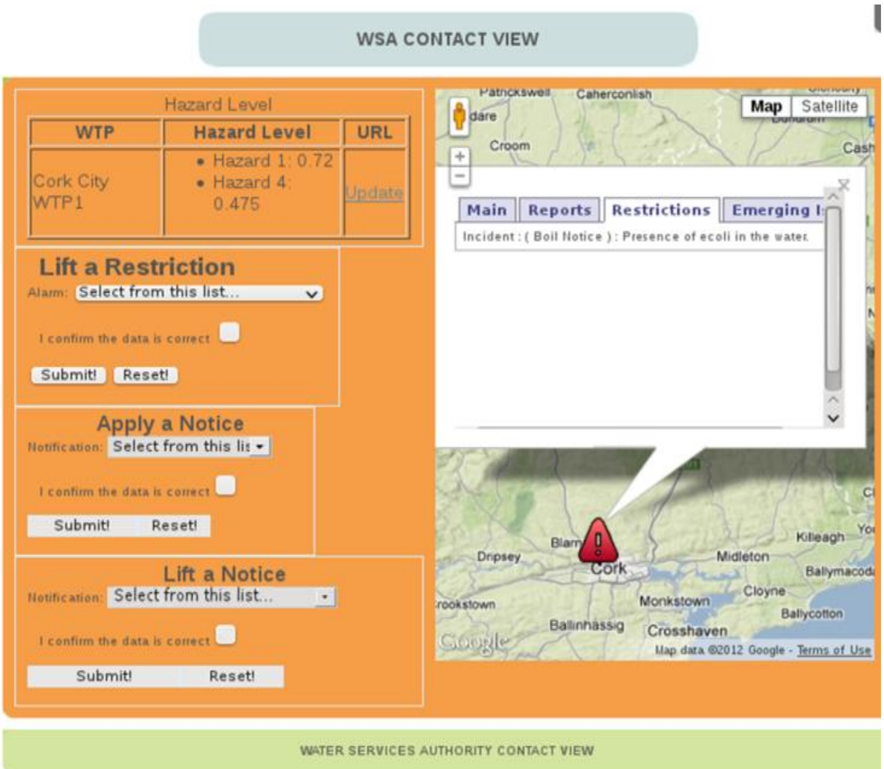


Figure 8. Change of the Warning Level

2.5 Evaluation

The testing and evaluation phase of the system was performed in three steps. During the first step, a number of demonstration meetings, with representatives from the key stakeholders of the SMS for the provision of safe drinking water for the Republic of Ireland, were organised in order to obtain an initial feedback about the potential usefulness of such a system. In the second step, the system was used/trialled by the Caretaker of the Newcastlewest DWTP, its associated Senior Engineer (WSA), the relevant EPA Inspector and the HSE Health Officer in real conditions for a period of six months. After that, in the third step, the goal was to submit questionnaires to its users from the previous step in order to assess its usability. Details of the testing and evaluation process and data, as well as detailed descriptions of the functionalities of this first working prototype system, are available in Foping (2012) and Foping & Dokas (2013, 2012).

2.6 Related Work

Guidelines, such as the World Health Organisation's Water Safety Plans (Davison et al., 2003) provide a framework on how to define “soft” procedures for the collection and dissemination of early warning information. These guidelines, however, are useful for early warnings, which could be perceived by agents located at the DWTP level only and not by agents located at the entire SMS, as described in the introduction. In short, one limitation of such guidelines is that they are not focusing on the early warning information, which may be perceived by agents located at different hierarchical levels within the SMS responsible for the provision of safe drinking water to the consumers.

The most relevant application to the SaaS-based system described herein is the WaterSentinel system (U.S. Environmental Protection Agency, 2005), The term “contamination warning system” was used by the U.S. Environmental Protection Agency instead of the term early warning system to describe this system because it was recognised that a reliable system providing an early warning of a contaminant prior to human exposure with public health impacts using today’s technologies may not be possible.

The conceptual architecture of WaterSentinel (U.S. Environmental Protection Agency, 2005) was defined in 2005. Some components of the system are:

- Online water quality monitoring, which use data from sensors and SCADA systems, are used first to define the expected “normal” levels of monitored parameters. Then, any changes from these expected “normal” levels of the parameters being monitored are interpreted as warning signs for potential contamination.
- Sampling and analysis of water at a predetermined frequency, which are used to detect contaminants that cannot be detected by the online monitoring system. In addition, water samples are collected in response to triggers from water quality monitors or other information streams to identify potentially unknown contaminants in the sample.
- Enhanced security monitoring, to monitor, collect and document security breaches, witness accounts, and notifications by perpetrators, news media, or law enforcement.
- Consumer complaint surveillance regarding unusual taste, odour, or appearance of the water is often reported to water utilities, which document the reports and conventionally use them to identify and address water quality problems.
- Public health surveillance, which can make use of data from existing syndromic surveillance conducted by the public health sector, from emergency medical service logs, emergency call centres, and poison control hotlines.
- A consequence management plan that details the treatment plant's response actions, along with those of the related local, state, and

federal agencies that should respond to a drinking water contamination incident.

The main difference of the prototype SaaS-based system described herein, compared to the drinking water systems that compile data from a variety of disparate sources, typically in a GIS platform, is its SaaS-based deployment, which allows its users to run the application inside their Web browser without the installation of further plug-ins. Another difference is that the SaaS-based early warning information fusion system "brings together", under one platform, different agents in different hierarchical levels of the SMS and, as result, can inform everyone associated with the safety of a DWTP at the same instance about any perceived early warning.

3. Overview of EWaSAP

It is generally accepted that the early detection of causal factors to a loss in a system, via the identification and the systematic collection of warning signs, is an important task in proactive risk management strategies. The timely observation of these signs, together with their justifications as early warnings, gives opportunities to take loss prevention actions. However, the safety field still lacks the concepts, tools, and measures to recognise warning signs prior to major failure events (Woods, 2009).

In order to provide a solution to this substantial challenge, the SCEWA team has introduced an early warning sign justification model and a structured approach called EWaSAP. This approach is based on STPA, which is a new hazard analysis technique based on the theoretical accident causality model called System-Theoretic Accident Model and Processes introduced by Prof. Nancy Leveson of MIT (Leveson, 2004 & 2011). STPA is a rigorous method for examining the control loops in the safety control structure of a system to find potential flaws and the potential for (and causes of) inadequate control.

A detailed description of EWaSAP, together with its related works, are available in Dokas et al. (2013). The following sections will describe the steps of EWaSAP and how it was applied to the chlorination process of a DWTP.

3.1 EWaSAP Steps

Table 1 depicts the steps of EWaSAP and how these are combined with the steps of STPA in a logical executional sequence. EWaSAP adds two types of steps into the STPA process. The first type is formed by Steps EW(1) and EW(2 a, b) which aim to establish a form of synergy between the system in focus and the systems in its surrounding environment. The rational for providing these steps is that, in many circumstances, the systems located in the surrounding environment of the system in focus may consider its safety as an important factor for their own safety. For example, an accident in the system under consideration may create potential harmful disturbances at the surrounding systems. Thus, a synergy, aimed at achieving improved awareness by exchanging early warning signs in the form of some sort of collective action, could be established forming something like a self-organised "system of systems".

The second type of EWaSAP steps is formed by Steps EW (3 a, b, c, d). These steps aim to identify the early warning signs within the system under assessment, by focusing on the characteristics of the sensory mechanisms that need to be installed, to make the controllers capable of providing situation awareness to other controllers within or outside the system whenever data indicating the presence of threats and vulnerabilities have been perceived and comprehended. EWaSAP names these actions as "awareness actions".

Table 1. EWaSAP steps as add-ons to STPA and their logical sequence of execution

Execution Sequence	STPA Steps	EWaSAP Steps	Description
1	STPA (1)		Identify the hazards in the system that may allow accidents to occur and translate these into top-level safety constraints.
2		EW (1)	**Aim:** Decide if there is anyone outside the system in focus (i.e. emergency responders) who needs to be informed about the perceived progress of the hazard or about its occurrence.
3	STPA (2 a, b, c)		a) Create the *control structure,* that is, a functional diagram depicting the components of the socio-technical system together with their control and feedback paths. The control structure diagram may be revisited to depict more information as the analysis progresses. b) Determine how hazards can occur. Hazardous states result from inadequate control actions in each of the system components that would violate the top level safety constraints. The inadequate control actions fall into the following four general categories: i. A required control action to maintain safety is not provided. ii. An incorrect or unsafe control action is provided that induces a loss. iii. A potentially correct or adequate control action is provided too early, too late, or out of sequence. iv. A correct control action is stopped too soon. c) Restate the inadequate control actions as safety constraints.
4		EW (2)	**Aim:** Identify useful sensory services (i.e. video surveillance cameras pointing at the system in focus) installed in or possessed by systems outside of the system in focus and establish synergy.
		a	For each top level safety constraint, identify those signs which indicate its violation.
		b	Find those systems in the surrounding environment with sensors capable of perceiving the signs defined in EW(2a) and request to establish synergy. The objective is to have the surrounding systems agree on the adoption of appropriate awareness actions, and therefore be able to transmit voluntary/synergetic early warnings to the appropriate recipients as per EW(1) about the occurrence of a top level safety constraint violation.

5	STPA (3 a, b)		Determine how the potentially hazardous control actions can occur and thus define how the safety constraints determined in Step (2) could be violated. a) For each controller in the control structure diagram, create a model of the process it controls. These models may contain information about the initial state of the controlled process, information on its current state, or information about the state of the environment around the controlled process. b) Examine the parts of the process control loops, within which each controller is embedded, to determine if they can contribute to or cause system level hazards. Each component of the control loop may lead to an inadequate control action. Thus, each of the general control loop components (i.e. the sensor, the controller, the actuator and the links between them) must be evaluated for their potential contribution to the hazardous control actions.
6		EW (3)	**Aim:** Enforce internal awareness actions.
		a	Describe what needs to be monitored, and what type of features/capabilities the sensors must have, in order to make the appropriate controllers capable of perceiving: a) the signs indicating the occurrence of the flaw b) the violation of the assumptions made during the design of the system.
		b	After the design trade-offs and when it is known which sensors have been selected for installation into the system, define which patterns of perceived data indicate the occurrence of the flaw and/or the violation of its designing assumptions.
		c	Update the process models of the controllers with appropriate awareness and control actions, which should be enforced based on the perceived early warning signs, in order to warn about, adapt to, or eliminate the causal factor to the loss which is present in the system.
		d	For each perceived warning sign of the previous step, define its meta-data/attribute values (i.e. how the message will be coded/written by the transmitter), so as to ensure that it will be perceived and ultimately understood by the appropriate controller/s.
7	STPA (4)		Restate any flaws identified in STPA (3b) as safety constraints and repeat STPA (3). If necessary, revisit the control structure diagram in Step (2) to depict new components or more detailed information on each identified component.

3.2 EWaSAP Implementation

The EWaSAP was applied at a drinking water treatment works located in Cork City that treats approximately 47,000 metres cubed of water (10 million gallons) per day and serves a population of 120,000. It is operated and managed by staff 24 hours a day, every day of the year.

Chlorine gas is the disinfection system employed at the water treatment works where EWaSAP was applied. The disinfection process in water treatment is the most important step to ensure that the water is safe to drink. Disinfection of water means the destruction of organisms to such low levels, that no infection of disease results when the water is used for domestic purposes, including drinking.

3.2.1 System Level Hazard and Safety Constraints (Step 1 of STPA)

In cases where the disinfection process stops or fails, there are normally no mitigation measures left to ensure that the distributed water from the water treatment works is free from hazardous micro-organisms. A potential result of this scenario could be severe illness to people drinking the water. The system level hazard in this case study was that "The water chlorination process cannot disinfect the water". Therefore, the system level safety constraint is "The water chlorination process should always be capable of disinfecting the water".

3.2.2 Agents Receiving Alerts in Case of Hazard Occurrence (Step EW1 of EWaSAP)

In case of the occurrence of the system level hazard awareness, action should be enforced by the appropriate controller to transmit a signal to the Senior Engineer of the WSA in which the water treatment works belongs. Ideally, the message should be perceivable and comprehensible by the Senior Engineer.

3.2.3 Basic Control Structure (Step 2a of STPA)

The basic control structure of the water chlorination process is depicted in Figure 9. It is an automated control process, with supervision by a human controller. In the water chlorination process chlorine is injected into the water via the Chlorine Injection element. The Disinfection Element is where the chlorine added to the water is mixed to disinfect the water. The pressure of the injection is regulated and checked by the Chlorine Supply Unit. To ensure that an adequate but not excessive amount of chlorine gas is administered to the water to disinfect it, Chlorine Residual readings are relayed from the Disinfection Element back to the Chlorine Supply Unit. The chlorine residual data received by the Chlorine Supply Unit are accessible to the Manager for inspection, who accordingly supervises the Chlorine Supply Unit, ensuring that the required control actions are executed in order to keep the water chlorination process functioning properly.

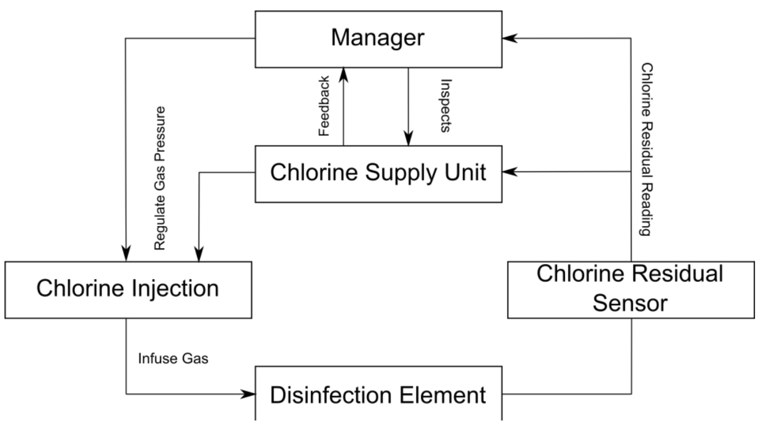


Figure 9. Control Structure of the Water Chlorination Process

3.2.4 Inadequate Control Actions and Safety Constraints (Steps 2b, c of STPA)

The main action of both controllers (i.e. the Chlorine Supply Unit, and the Manager) is to regulate the chlorine gas pressure. The possible categories of inadequate control actions, according to STPA, fall into four general categories as Table 2 shows. The inadequate control actions are then restated to define the safety constraints. Safety constraints define the conditions that, if breached, could potentially allow the process to enter into a hazardous state.

Table 2. Inadequate Control Actions (ICA) and Safety Constraints (SC)

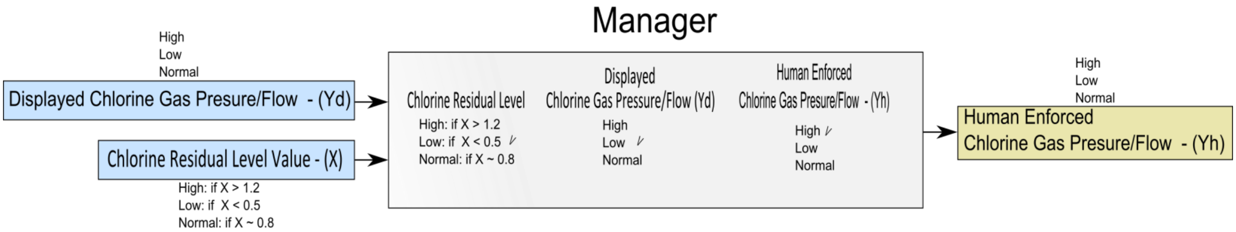
The regulated chlorine gas pressure is:			
ICA1	not provided	SC1	Appropriate chlorine gas pressure should always be provided to the chlorine injection unit from the chlorine gas supply unit.
ICA2	provided incorrectly	SC2	The injected chlorine gas should always correspond to the regulated chlorine gas pressure.
ICA3	provided too early, too late, out of sequence	SC3	An adequate chlorine gas pressure supply should not be provided too early, too late, or out of sequence.
ICA4	stopped too soon	SC4	The correct chlorine gas pressure should not be stopped too soon.

3.2.5 Signs indicating the Violation of System Level Safety Constraints and their Potential Perceivers (Steps EW 2a, b of EWaSAP)

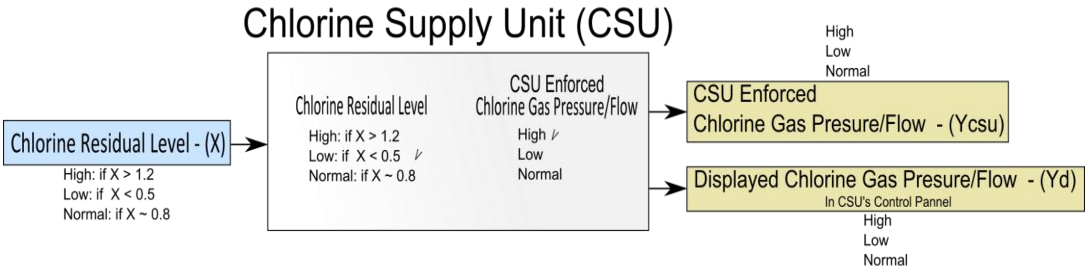
Potential agents outside of the system under assessment, who can perceive signs indicating the violations of a system level safety constraint, could be the consumers close to the waterworks or the laboratories conducting the periodic testing of the water. For example, the consumers close to the waterworks may experience an unpleasant or unusual taste or odour in their tap water. In an attempt to establish synergy, the personnel from the water treatment works have informed consumers about these warning signs and about their proper response, in case they are perceived.

3.2.6 Process Models (Step 3a of STPA)

The human and the automated controller in this case possess a model of the process they control. The aim of this step is to “layout” these models, as depicted in Figure 10.



(a)



(b)

Figure 10. Process Models of (a) The Manager and (b) Chlorine Supply Unit

For example, the Chlorine Supply Unit regulates the chlorine gas pressure based on feedback information on the chlorine residual level (X) obtained from the sensor. In cases where the chlorine residual level is low (i.e. X<0.5), the Chlorine Supply Unit should enforce a control action to set the chlorine gas pressure to high. When the residual chlorine level is high (i.e. X>1.2), the Chlorine Supply Unit should enforce a control action to set the chlorine gas pressure to low. The aim is to maintain the chlorine residual level in the water at normal levels (i.e. X~0.8). In addition, the human controller, who oversees how the water chlorination process is operated, monitors the chlorine residual level (X) from the sensor and the chlorine gas pressure (Yd), which is displayed by the Chlorine Supply Unit. If the chorine residual level and the chlorine gas pressure are low at the same time, then he needs to manually set the chlorine gas pressure to high.

*3.2.7 **Process Control Loop Flaws (Step 3b of STPA)***

In this step, each element of the process control loops, depicted at the control structure (see Figure 9) is examined, to determine how it can contribute to the system level hazard. The aim is to find potential flaws within the process control loop that may lead to inadequate control actions. Some of the identified flaws on the control loop process are included in the second column of Table 3.

*3.2.8 **Identify the Features and Capabilities of Sensors as well as the Warning Signs (Steps EW 3 a, b of EWaSAP)***

The goals of these steps are to: define the data/signs indicating the presence of flaws in the feedback loops of the control structure; and specify the features and characteristics of the sensors at the appropriate level of the hierarchy, in order to be able to perceive these data.

Table 3. Flaws, Sensor Features and Warning Signs

Safety Constraint	Flaw	Features and Characteristics of Sensor	Signs
SC1, SC3, SC4	Incorrect or no information provided, due to disturbance (soiling) of the sensor on the residual chlorine monitor.	1. Should be able to visually inspect the state of the sensor on the residual chlorine monitor at regular intervals.	1. Soil (grey or dark points) in the sensor. 2. Sensor is seen to be physically damaged. 3. Corroded (change in its colour). 4. Last visual inspection was six months ago.
SC1, SC3, SC4	Measurement inaccuracies in residual monitor due to lack/wrong calibration, sitting of sensor in wrong location.	1. Should be able to see and understand the monitoring data of the sensors. 2. Should be able to see the independent agent's verification data after calibration. 3. Be informed that the monitoring data are verified by independent testing with another monitor at six- monthly intervals. 4. Be able to see whether profiling of the tank was conducted. 5. Become aware if variations/differences are noted in the residual chlorine data post the tank.	5. LED displaying value of less than 0mg/l on residual chlorine monitor. 6. No certificate on verification check or certificate indicates that the validation check is incorrect. 7. Testing interval exceeds six months. 8. No profiling data available. 9. In case of spot check, there are significant differences in results from the LED readout.
SC1, SC3, SC4	Inadequate operation of the sensor on the residual chlorine monitor, due to damage, lack of maintenance, lack of calibration.	1. Should be able to visually inspect the sensor regularly. 2. Become aware that the sensor is subject to regular preventative maintenance.	10. No readout, blank LED readout. 11. LED less than 0mg/l. 12. Testing interval exceeds six months. 13. See the damage (i.e. broken pieces, deformation, etc.) to the sensor. 14. See the components dismantled.
SC1, SC2, SC3, SC4	Incorrect readout on the residual chlorine monitor at the disinfection element.	1. Be aware that the residual chlorine monitor is reading at least 0.45mg/l at all times.	15. Readout on residual chlorine monitor is less than 0.45mg/l.*
SC1, SC3, SC4	Feedback delays from the residual chlorine monitor, due to damaged/corroded line.	1. Should visually inspect that the lines are replaced at the recommended and appropriate intervals.	16. Cable cut or protective cover removed on part of the line. 17. Sensor discoloured/reddish colour on sensor.

		2. Should be aware that integrity checks/inspections have been undertaken on the line at regular intervals.	
SC1, SC3, SC4	Inadequate or missing feedback from the residual chlorine monitor, due to line failure.	1. Should be able to see the feedback information. 2. Should be able to perceive if there is a line failure.	18. No readout on LED. 19. No readout on LED and maintenance works on-going in the vicinity of line at the same time.
SC1, SC3, SC4	Incorrect flow of the chlorine gas through the chlorinator in the chlorine injection unit.	1. Should be able to see that the flow meter in the chlorinator is at the correct level.	20. Flow meter reading less than 1.8kg/hour.
SC1, SC2, SC3, SC4	Missing chlorine flow information (from the chlorine supply unit), due to fault with chlorine supply unit.	1. Should be able to see the movement in the chlorinator flow meter. 2. Be aware that the valve on the chlorine gas supply line is not shut off.	21. No movement in the chlorinator flow meter (in the chlorine injector room). 22. Valve on the chlorine gas supply line is shut off.
SC1, SC2, SC3, SC4	Chlorine supply unit incorrectly configured by the installer.	1. Should see that chlorine supply unit is installed by qualified, experienced installers/fitters as per the correct specifications.	23. Company not listed as an authorised and certified installer of chlorine supply units. 24. Installed by an inexperienced and newly-hired installer.
SC1, SC3, SC4	Inappropriate pressure gauge reading on the changeover control panel for a new drum.	1. Should be able to observe that that gas pressure readout for a new drum is > 3.5 bar.	25. Pressure gauge reading is not between 3.5 and 6 bar.*
SC1, SC3, SC4	Incorrect operation of the alarm.	1. Be able to hear alarm if the reading on the pressure gauge of the changeover panel is ≤ 1 bar for 20 minutes. 2. See the LED indicators about the status of the power and of the reserve drums.	26. No sound from the alarm when the pressure gauge reading on the changeover panel is ≤ 1 bar for 20 minutes.* 27. No light on LED indicating that the “Power is on”. 28. No light on LED indicating “No Reserve”.*
SC1, SC3, SC4	Inadequate pressure gauge reading in the chlorine gas supply room.	1. Should see that the pressure gauge reading is > 1 bar.	29. The pressure gauge reading is ≤ 1 bar for 20 minutes.
SC1, SC3, SC4	Process model incomplete or incorrect, due to lack of training/awareness/ knowledge.	1. Should see that Manager is certified and has the appropriate training and experience.	30. Absence of CPD (continuous professional development) records. 31. References with adverse comments.

SC1, SC2, SC3, SC4	Ineffective/missing oversight, due to absence from control office (work pressure)/poor judgement on the existence of potential threatening conditions.	1. Should see the Manager and his/her attendance records; 2. Should see the audit trail on tasks performed/completed.	32. Physical effects on health and well-being. 33. Number of records with additional time worked.
SC1, SC2, SC3, SC4	Inappropriate control of the chlorine injector, due to incorrect settings.	1. Should see that the settings have been determined correctly and verified by the Manager. 2. Should be able to identify if there are any differences in the results on the monitored residual chlorine in the final disinfected water compared to the expected results.	34. No record of the calculations for the chlorinator scale. 35. Chlorinator flow meter readout is not in accordance with calculations of the chlorinator scale.
SC1, SC2, SC3, SC4	Inadequate operation of the injector, due to blockage/damage to the injector mechanism.	1. Should be able to see that there is no chlorine flow. 2. Should be able to visually see that the chlorine is being injected into the water. 3. Should be able to identify if there are any differences in the results on the monitored residual chlorine in the disinfected water compared to those expected.	36. LED is reading 0. 37. Flow meter is reading 0.* 38. No visible disturbance in the water at the point of chlorine injection. 39. Residual chlorine reading not less than 0.45mg/l when the chlorine supply is 1.8kg/hr.
SC2	Delayed operation of chlorine gas infusion due to environmental conditions (freezing)/damage or corrosion to pipe work.	1. Should be able to feel that the temperature is low or read the thermometer. 2. Should be able to see that the chlorine gas infusion line is appropriately placed and that it is in good condition.	40. Temperature readout < 0. Feel cold weather conditions. * 41. See damage or deformation to infusion line.
SC1	Properties of the water parameters (i.e. pH, turbidity) not identified.	1. Should see that the data on the water characterisation is available.	42. No pH data available. 43. No testing equipment available.

The * symbol indicates a warning sign that already exists within the SMS.

In this case, the appropriate hierarchical levels capable of perceiving these signals are the manager and operators of the water treatment works, as well as the state agencies' auditor. The results of this step are depicted in the third and fourth column of Table 3. Therefore, the system level safety constraint is "The water chlorination process should always be capable of disinfecting the water".

*3.2.9 **Define the Awareness Actions and the Meta-Data Description Values for each Early Warning Sign (Steps EW 3 c, d of EWaSAP)***

In Step EW(3c), the objective is to define appropriate awareness and control actions, as well as the conditions under which these should be enforced, based on the perceived early warning signs, so that to warn about, adapt to, or eliminate the flaws which are present in the system. Indicative examples of the outcome of these steps are given in Table 5. Examples of meta-data early warning descriptions are depicted in Table 6.

3.3 Results

As a result of using EWaSAP, a total of 43 warning signs were identified, 37 of which were new and six were confirmed to exist already, as indicated by the symbol "*" in Table 3. In essence, with EWaSAP it was possible to identify the early warning signs that existed in the SMS in the waterworks and to identify many more.

Table 5. Examples of Awareness Actions

Controller	**Indicative Updates of Manager's Process Models**
Manager	IF “LED is reading 0” AND “Flow meter is reading 0” AND “No disturbance at the point of chlorine injection” AND “Result from LED readout and final disinfected water differs from the one calculated by the certified formula” IS TRUE THEN “Inadequate operation of the injector due to blockage/damage to the injector mechanism” IS TRUE AND Enforce Awareness Action “TRANSMIT ALERT” OR “TRANSMIT ALGEDONIC SIGNAL”
Manager	IF “Temperature readout < 0” OR “See damage or deformation to infusion line” IS TRUE THEN “Delayed operation of chlorine gas infusion due to environmental conditions (freezing)/ damage or corrosion to pipe work” IS TRUE AND Enforce Awareness Action “TRANSMIT ALERT” OR “TRANSMIT ALGEDONIC SIGNAL”
Manager	IF “No readout on LED” IS TRUE THEN “Inadequate operation of the sensor within the residual chlorine monitor, due to damage, lack of maintenance, lack of calibration” OR “Inadequate or missing feedback from the residual chlorine monitor, due to line failure” IS TRUE AND Enforce Awareness Action “TRANSMIT WARNING”.
Manager	IF “LED less than 0mg/l”. IS TRUE THEN “Inadequate operation of the sensor within the residual chlorine monitor due to damage, lack of maintenance, lack of calibration” IS TRUE AND Enforce Awareness Action “TRANSMIT WARNING”.

Table 6. Examples of Early Warning Signs Meta-data Descriptions

Awareness Action	**Meta-Data of the Associated Safety Constraint**	**Meta-Data of Early Warning Signs Involved**						**Meta-Data of Transmission**		**Warning/Alert**
	Violated Safety Constraints or Assumptions	**Warning Signs**	**Type of Warning Sign**	**Time of Observation**	**Value**	**Physical Source of the Sign**	**Sensor to Control Channel Status**	**Signal Type**	**Receiver**	**Receiver Perception Capabilities**
TRANSMIT ALERT or TRANSMIT ALGEDONIC SIGNAL	SC1, SC2, SC3, SC4	"LED is reading 0" "Flow meter is reading 0" "No disturbance at the point of chlorine injection" "Result from LED readout and final disinfected water differs from the one calculated by the certified formula"	All Visual	Set the time/date of the perception of each sign	TRUE	Manager's Office Chlorine Supply Unit Chlorine Injection Unit Manager's Office	Human Visual Channel	Electronic Email Telephone	Senior Engineer State Agencies	Email Fax Telephone
TRANSMIT WARNING	SC1, SC3, SC4	"LED less than 0mg/l"	Visual	Set the time/date indicating when the early warning sign has been perceived	TRUE	Manager's office	Human Visual Channel	Verbal	All Staff	Electronic

After a meeting with the manager and staff of the water treatment works, the findings of the case study were discussed and all warning signs, which are shown in Table 3, were validated as true findings because they were tacitly "used" in everyday operations.

Fourteen warning signs were deemed by the manager and staff to be of sufficient importance to be incorporated into the existing SMS at the water treatment works. These warning signs were selected based on their potential impact on the water treatment process.

4. A Hazard and Early Warning Sign Analysis Editor

In order to support analysts in their efforts to create models of possible accident scenarios in critical infrastructures and to identify their associated early warning signs, the SCEWA team designed and developed three graphical modelling languages based on the fundamental concepts of STPA and EWaSAP. Each graphical element in the languages represents a model of a STPA/EWaSAP concept. The three graphical modelling languages were incorporated into a prototype open source software editor, where each element can be connected with other graphical elements based on a predefined syntax.

The graphical modelling languages and the software editor created were based on Domain Specific Modelling technologies. As result, the users of the editor can generate executable computer code through their STPA/EWaSAP graphical models. Thus, such a software tool can support analysts in developing and updating the knowledge base of computer-based early warning systems. In the following paragraphs, the specifications of the graphical modelling languages and some features of the software editor will be presented. A detailed description of the design, development and evaluation process, as well as a review of the relevant literature is available in Imran (2012).

4.1 Graphical Modelling Languages Specifications

After defining a hazard, the analyst who uses STPA/EWaSAP must execute the following generic tasks:

1. Represent the real-world elements, which comprise the reference system (i.e. create a control structure diagram), and define the feedback control process(es) responsible for keeping the system in a safe state.
2. Define the conditions that may lead to accidents (i.e. define the inadequate control actions) based on the feedback control processes which were identified in the previous task.
3. Define the flaws and the early warning signs associated with each feedback control process.

Based on the above tasks, the SCEWA team defined three task-oriented domain specific languages; namely the Control Structure Modelling Language (CSML), Inadequate Control Action Modelling Language (ICAML), and Analysis Modelling Language (AML). The purpose of the CSML is to enable analysts to define the boundaries of the reference system and its key elements. The purpose of the ICAML is to enable users to create models that represent the feedback control processes of the reference system and to define their inadequate control actions. The purpose of the AML is to allow the users to create models of accident scenarios and to define the early warning signs at each causal factor to a loss.

The specifications of the three graphical modelling languages are depicted in Figures 11 to 13, using Unified Modelling Language models.

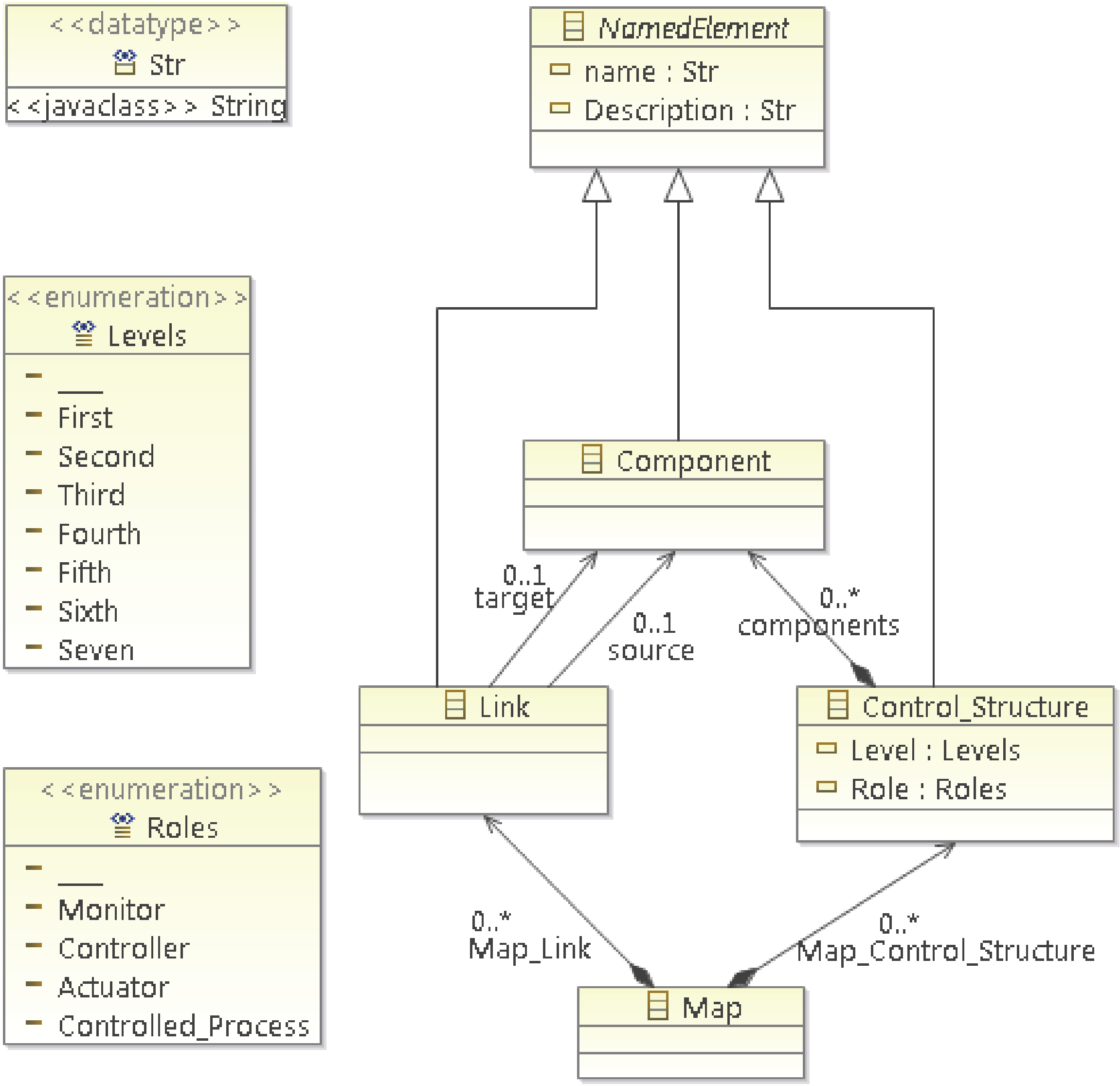


Figure 11. The Specification of CSML

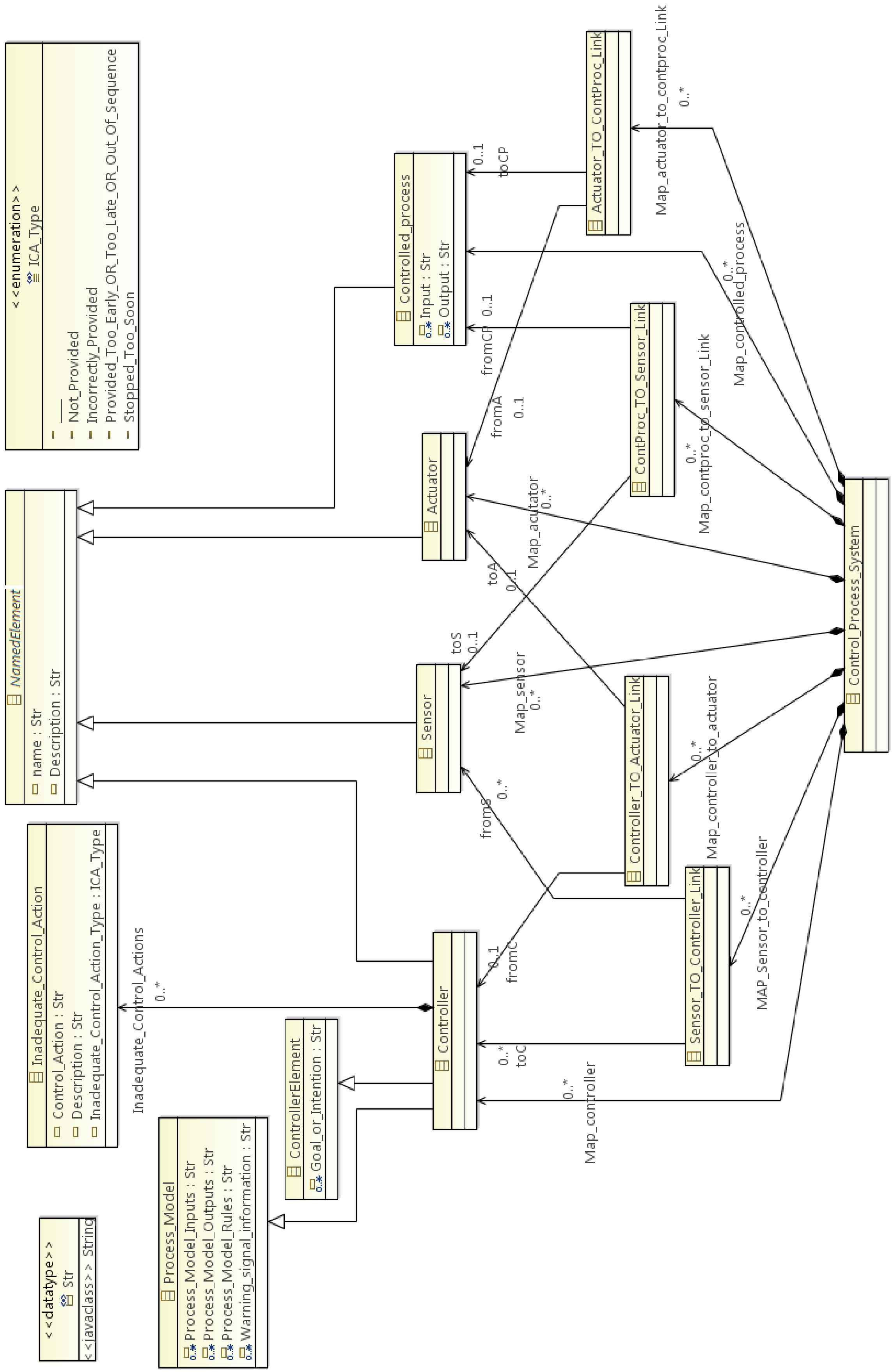


Figure 12. The Specification of ICAML

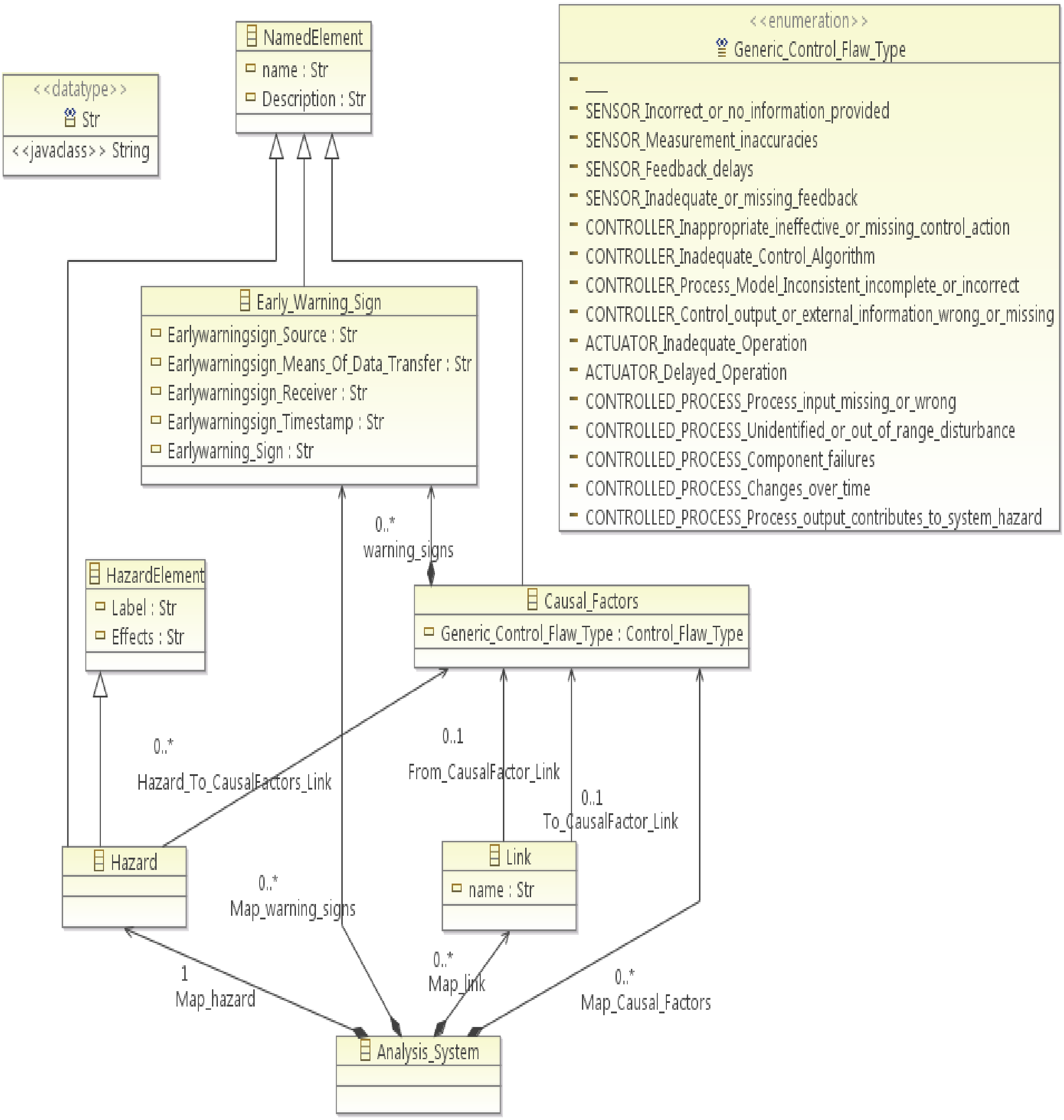


Figure 13. The Specification of AML

4.2 Workflow

The workflow of conducting hazard and early warning analysis based on the combined STPA/EWaSAP procedure, using the prototype software editor, is presented in the following paragraphs. The user activities, which can/should be done with the editor, are shown in Figure 14.

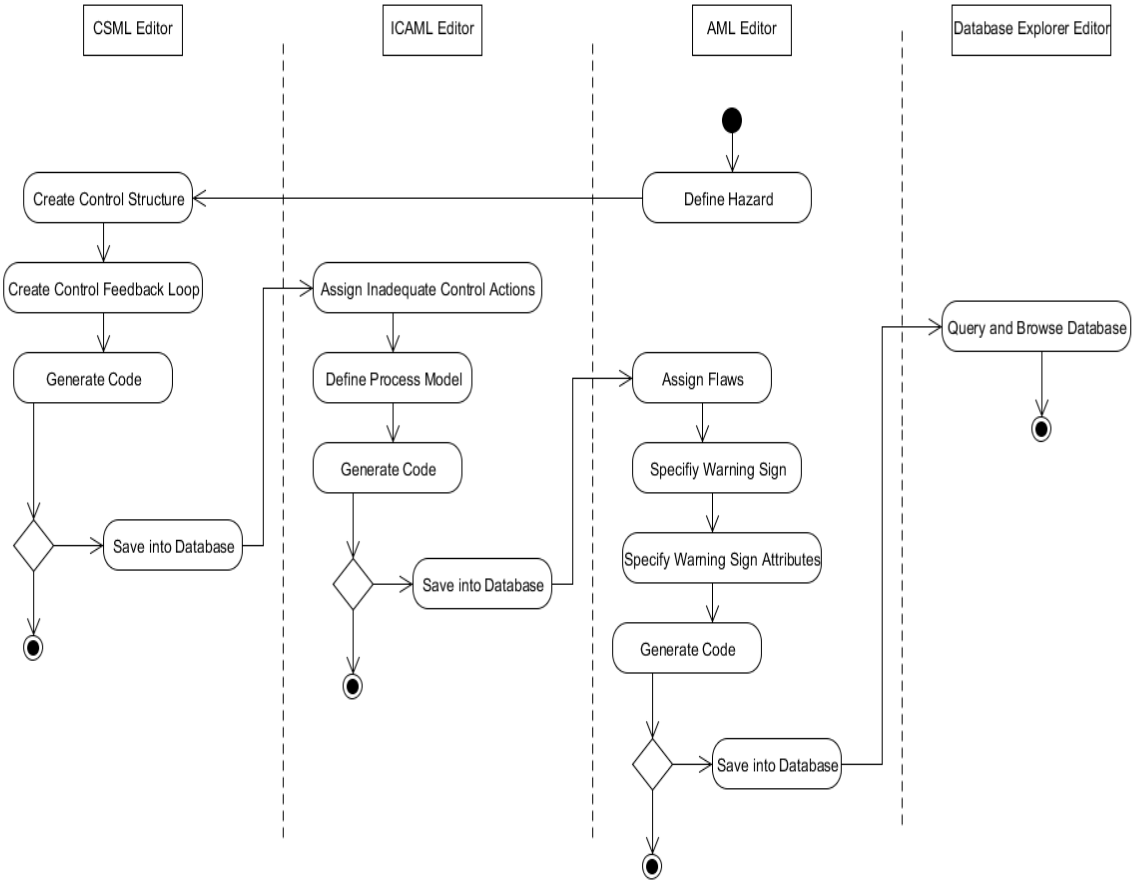


Figure 14. UML Activity Diagram of Prototype Early Warning Sign Analysis DSML Software Tool

The AML editor is initially used by the user to define hazards that may escalate into accidents. The user then creates the control structure of the reference system with its feedback control processes, using the CSML editor. Figure 15 shows some elements of the user interface CSML dedicated editor. The palette of the CSML editor contains the graphical icons representing the concepts of "control structure", "component" and "link", which are used to draw control structure diagrams and feedback control processes on its editor view. The attributes of each drawn model are defined and updated using the property view, where dropdown menus enable, in some cases, the users to select an appropriate attribute value.

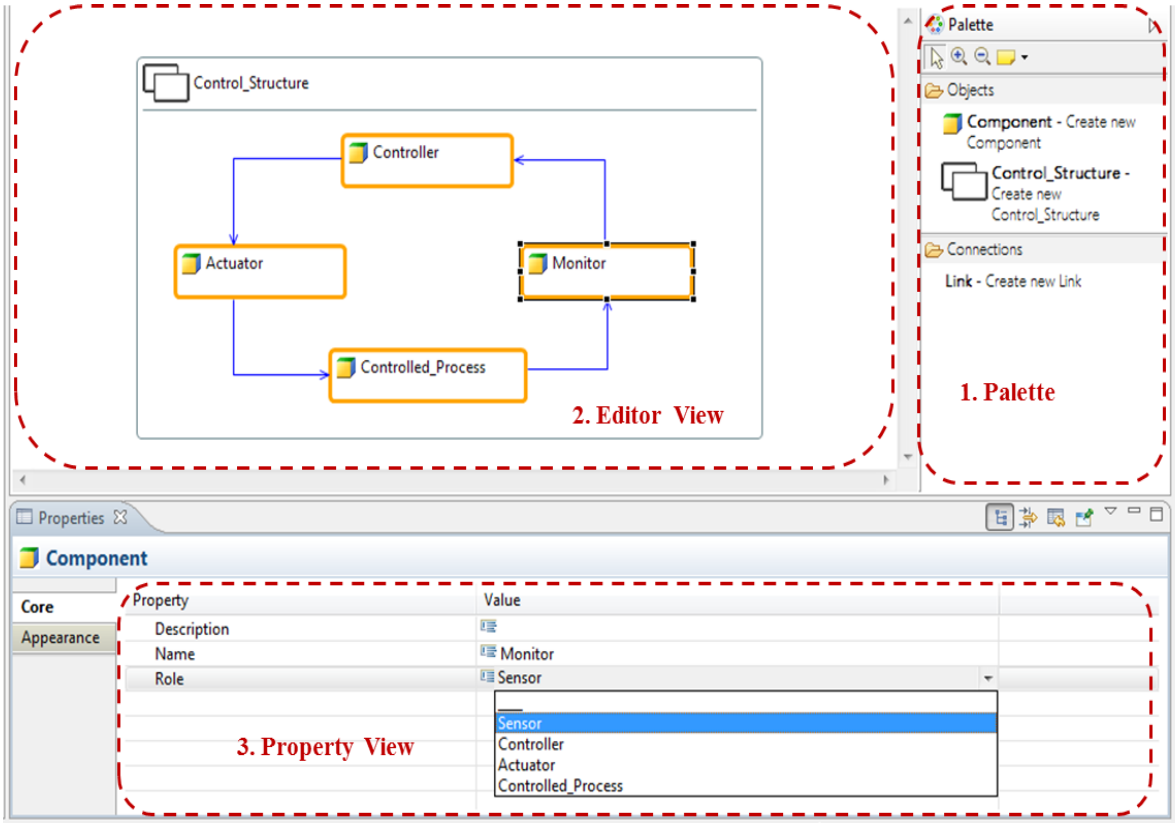


Figure 15. The CSML Editor

If the user desires, he can save the models drawn on the CSML editor, generate computer code and continue his analysis. As the analysis proceeds, the need to assign inadequate control actions to each controller of the feedback control processes and to define the process model for the controller is satisfied by the ICAML editor. Figure 16 shows part of the user interface ICAML dedicated editor. The palette of the ICAML editor contains a set of graphical icons representing the concepts of "actuator", "controlled process", "controller", "inadequate control action", "sensor" and "links". These graphical icons are used to draw feedback control processes on the editor view and to assign inadequate control actions to their controllers. The user can select the appropriate type of inadequate control action from a dropdown menu available at the property view. In addition, the process model of each controller of the control structure can be defined and updated by entering data into a text field in the property view.

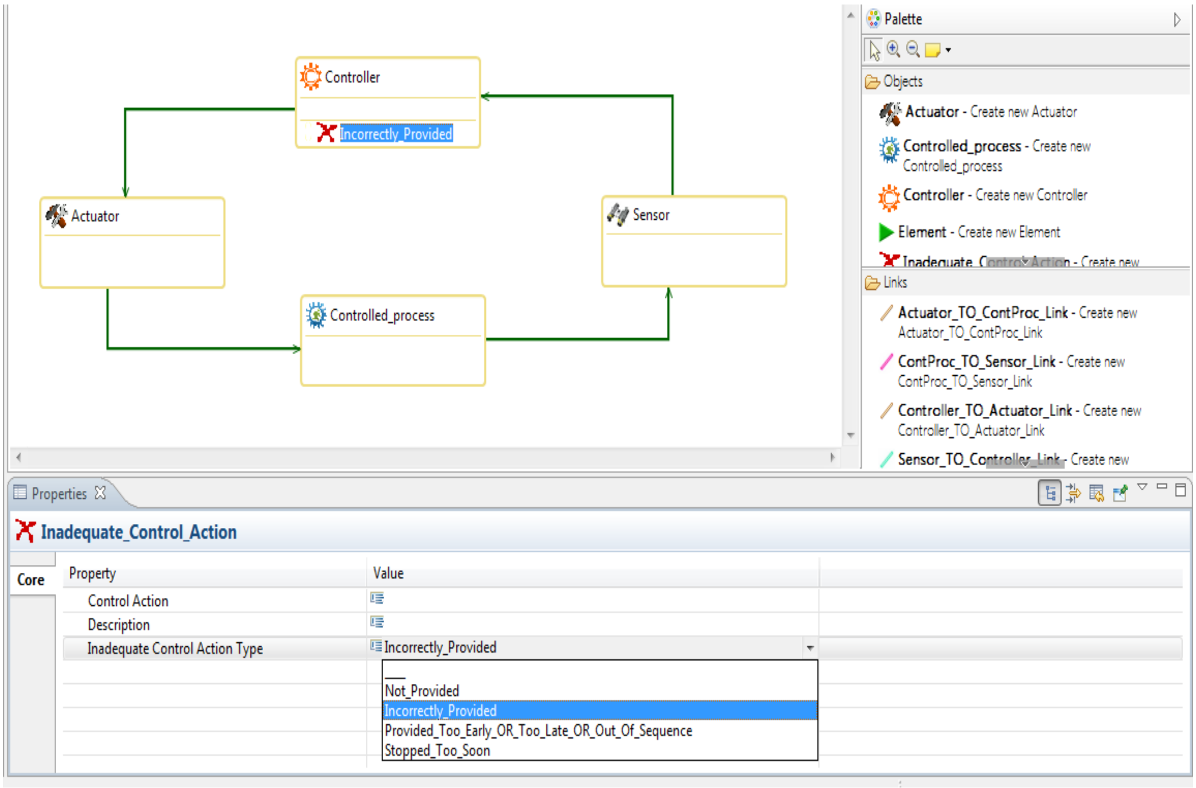


Figure 16. The ICAML Editor

Thereafter, the AML editor is used to define the possible flaws and warning signs of a feedback control process. Figure 17 shows the user interface of the AML editor. The palette of the AML editor contains a set of graphical icons representing the concepts of “hazard”, “causal factors” and “links”. With these graphical icons, the user can create a hazard analysis scenario, where the relations between the hazard and its causal factors are defined. The properties, which are visible from property view, enable users to select the appropriate type of flaw from a dropdown menu and to define its associated early warning signs.

The computer code can be generated from the models drawn in each of the dedicated editors, into either XML or Java format. Figure 18 shows a snippet of JAVA code generated using the AML editor.

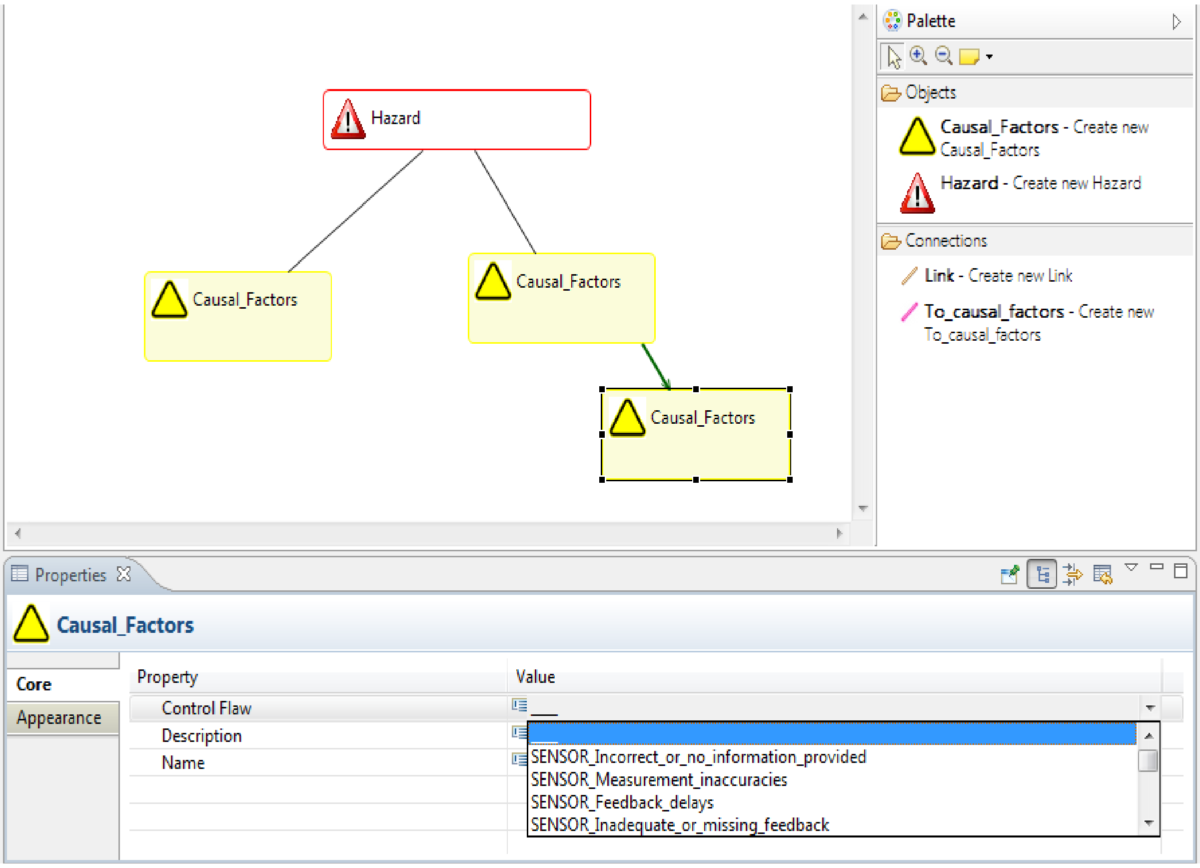


Figure 17. The AML Editor

```
public class Analysis{
class hazard {
    String name = "The water disinfection process should always disinfect the water";
    String Lbl = "H1";
    String Eff = "Untreated drinking water supply";
    String Desc = "In this water treatment process, raw water is taken from a river a
}

class Causalfactor1 {
    hazard h = new hazard();
    String Hazard_name = h.name;
    String Hazard_label = h.Lbl;
    String Hazard_Effect = h.Eff;
    String Hazard_Descripton = h.Desc;

    String CausalFactor_Flaw = "SENSOR_Incorrect_or_no_information_provided";
    String CausalFactor_Name = "Pressure guage reading";
    String CausalFactor_Description = "Inappropiate pressure guage reading on the cha

    String EarlyWaring_sign = "Pressure guage reading is not between 3.5 and 6 bar";
    String EarlyWaringSign_source = "Pressure guage reading on the changeover control
    String EarlyWaringSign_means_of_data_transfer = "Observation";
    String EarlyWaringSign_receiver = "Water treatment works Opertor (person responsi
    String EarlyWaringSign_timestamp = "20101223152609";
 }

 class Causalfactor2 {

 class Causalfactor3 {
}
```

Figure 18. Generated Java Code

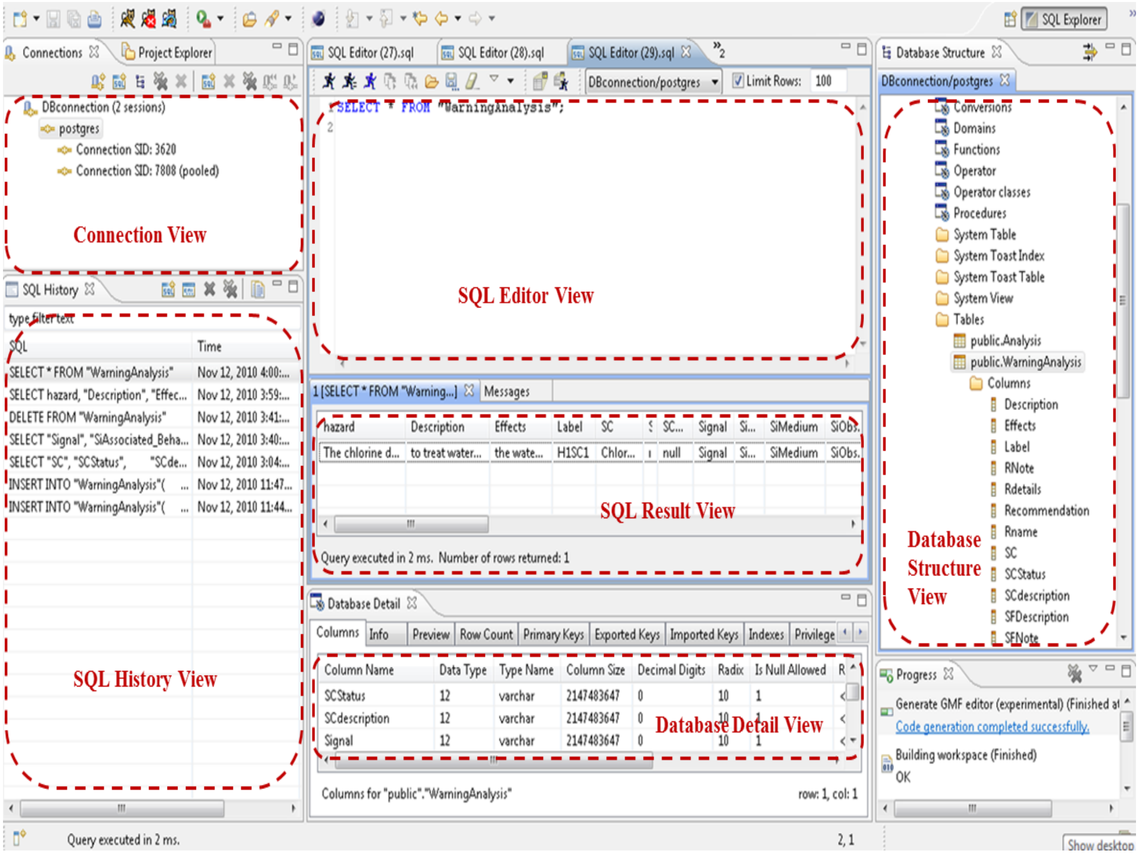


Figure 19. The Database Explorer Editor

Furthermore, a database explorer editor enables users to query and browse the user data. As shown in Figure 19, the main components of the database explorer editor layout include the: Connections View for managing database connections; SQL Editor View to execute queries and display its execution time; SQL Result View to display the results on executing SQL statements; and SQL History View to display successfully executed queries. The information about the number of times the query is executed and the date and time of its execution is also provided in SQL History View. The Database Structure View and Database Detail View allow the user to explore the database tables and to view information about the data types on its records.

5. Discussion

5.1 SaaS-based System

The experts, with whom the SCEWA team liaised in order to design and develop the system, also mentioned that they are using "homemade"/legacy systems to record the early warning signs, which are defined by the legislations and the official procedures. However, these systems are not "connected" with similar systems, which other stakeholders are using. Thus, they recognised the usefulness of using one system that collects and disseminates perceivable early warnings by the whole spectrum of agents that belong within this complex SMS.

On the other hand, the users were sceptical of the potential data overflow, which the reporting emerging issues and early warnings by the sensors may generate to the stakeholders of the SMS. The data overflow could generate new threats. As a result, they proposed to include some sort of validation procedure before any emerging issues reported by the Caretakers will be visible to other stakeholders. This comment has forced changes and additions into the validator module at the business logic layer of the system.

Furthermore, some experts were discussing whether a court of law will have the potential to use the recorded data of the system during a court case, after the occurrence of an outbreak. As they mentioned, if such potential exists, then a number of agents of the SMS may be cautious about adapting the early warning information fusion system. This is something that was not possible to be assessed with certainty and which needs very careful consideration. However, it is technically possible to address possible future requirements by deleting some data from the database in an automatic manner.

All experts agreed that such a solution has the potential to save resources and money. They did raise questions about the maintenance of such a system in practice. Indeed, there should be one office or organisation within this complex SMS that will be responsible for updating and maintaining such a system.

Another issue that emerged during the use of the SaaS-based system in real conditions, was that its usage by the stakeholders declined over time. The users suggested the introduction of some kind of motive(s) to use it as frequently as they did during the first weeks of testing. These motives may include rewards and formal acknowledgments for reporting early warnings in a timely manner.

Overall, from the testing and evaluation of the system, it became apparent that the potential of using a SaaS-based approach for the provision of early warning information fusion services into the domain of critical infrastructure safety seemed quite promising, and there is evidence indicating the potential of this system to evolve and become a new paradigm in the provision of early warning services for complex socio-technical systems. However, more work is needed to fully comprehend all aspects of the potential benefits of such a service.

The long-term goal is to find ways of addressing the issues mentioned by its users and to systematically study how SaaS-based early warning information fusion systems could be integrated into complex SMSs for different types of critical infrastructures, as proactive risk management tools.

5.2 EWaSAP

EWaSAP is the result of an effort to create new concepts and better tools to recognise warning signs prior to failures and accidents. While STPA aims at designing safe and resilient feedback control loops within a complex system, EWaSAP aims to enhance the awareness about the threats and vulnerabilities, which may be present in a system during its operations phase, via the systematic collection and analysis of their warning signs.

EWaSAP helps analysts to identify, and most importantly to justify, a significant number of early warnings to accidents. Indeed, EWaSAP makes analysts and designers think, even from the early design phases of the system, how to enhance the perception and comprehension capabilities of the system, as well as the communication of the warning signs about the presence of the contributing factors which may lead to accidents. A very useful feature of EWaSAP is the introduction of the notion of awareness actions. The awareness actions of EWaSAP force analysts to consider the reaction of the system to a perceivable early warning sign, which indicates the presence of a flaw or threat.

As result, EWaSAP guides analysts to select and configure the appropriate sensors within a complex system and define appropriate reactive strategies into the process models of the controllers. This is a major contribution to the systems safety and resilience engineering literature, as it is one of the first structural approaches which can be used for the design and development of resilient systems.

5.3 Relations to Policy

The Irish Government has declared that it wants “intelligent information and communications systems deployed in the public service to deliver faster, better and more efficient information to all”. The SaaS-based system presented herein is a prime example of what SaaS technology can provide to service the Irish Government’s requirements. It has the potential to greatly improve communications between the many stakeholders involved in this complex socio-technical domain and can deliver this information in a timely manner to all stakeholders and the general public.

With the reduction in staffing numbers in the public sector in Ireland and the Government’s objective of leveraging greater productivity with less resources, this is presenting a challenge to many parts of the public sector, not least to the authorities responsible for the provision of drinking water. The application of EWaSAP can collect a comprehensive set of early warning signs for this domain and it has the potential to greatly assist Managers to decide where best to deploy resources. The use of EWaSAP, together with the application of the SaaS system, can provide for greater efficiencies even with reduced resources.

6. Recommendations

Monitoring, detecting and eliminating harmful agents in the water are very important task. These tasks should be supported and embraced. However, in order to ensure the safety of the water, it is equally important to monitor and assess the "safety health" of the entire system, which is responsible for the provision of safe drinking water to the consumers. Therefore, it is recommended to strengthen the mechanisms and procedures that are used to detect dysfunctional interactions between the different actors and agencies responsible for the provision of safety, as well as the identification of flaws which can be classified as having managerial and safety culture characteristics.

The systems safety and resilience engineering domain possesses appropriate methods and tools that can be used to identify and react to various hazardous scenarios within organisations, which under the right conditions may lead to accidents. It is recommended, thus, that some of the tools and the methods that are used by a monitor and control mechanism, which is responsible for the timely detection of flaws within the system responsible for the provision of safe drinking water, originate from, among others, the systems safety and resilience engineering domain. STPA and EWaSAP may be, for instance, two potential useful tools. In addition, the SaaS-based early warning information fusion system presented herein provides a framework by which all stakeholders in this domain can more effectively communicate and exchange information in a timely manner more effectively and efficiently.

The task of safety inspection is not easy. An inspector, for instance, has to inspect multiple and unfamiliar DWTPs. There is a great variability on the potential defects that an inspector may find and many times the defects are described only in general terms. Furthermore, there is little literature available that breaks down the safety inspection task and identifies how its decisions are made (Woodcock, 2013). Thus, it is not strange that EPA inspectors do not follow a specific method or protocol when doing inspections in DWTPs. Nonetheless, it would be beneficial if an inspection method and protocol for DWTPs would be available to them. Therefore, it is recommended to set, as a future goal, the creation of an inspection method/protocol for DWTPs.

The agencies and some local authorities are equipped with legacy systems that record and analyse the early warning signs, which are defined by legislations and official procedures. However, these systems are not “connected”, making it difficult to retrieve information that is needed, in order to reach a desirable situation awareness. Furthermore, the users of these systems cannot report other – non-predefined by the legislation - early warnings. The early warning fusion system developed by the SCEWA team has shown that a SaaS-based system could be a part of the overall solution to this, due to its benefits, such as a low maintenance and operating cost, and the leveraging of the economy of scale. Therefore, it is recommended to: a) strengthen and support any tasks that aim at the interoperability and exchange of data between existing systems that are used by the relevant stakeholders; b) consider technologies that make use of the SaaS model as part of the possible solution to this problem.

7. Conclusions

The SCEWA project created methods and tools that could make a significant impact on the proactive risk management of critical infrastructure and could also spark new dimensions of the use of the SaaS business model and of the STAMP accident model in the domain of proactive risk management and resilient engineering.

Specifically, the project **has proven the concept that the SaaS deployment model can be used in the context of complex socio-technical systems to provide early warning services**. The benefits of SaaS include:

a) Its high adoption potential by users, which is based on that fact that SaaS applications are available from any computer or any other device that has Internet access.

b) Lower initial cost for its users because they are not required to pay licence fees.

c) Easy to update and upgrade the software because there is only one software that needs to be updated and it is located in the servers of the provider.

d) Seamless integration with legacy systems which can be achieved with appropriate Application Programming Interfaces to allow the integration of a SaaS system with existing legacy systems that are in operation in various organisations.

The limitations of the SaaS model which were recognised in this case were:

a) The ownership of the data and how these may be used by a court of law.

b) The security of the application and its behaviour in case of malicious cyber attacks.

c) The introduction and utilisation of proper motives in order to make everyone involved in the provision of safe drinking water to the consumers use the SaaS early warning fusion system on a daily basis.

The project has also introduced a very comprehensive early warning sign identification approach which can help analysts to identify and justify sets of perceivable data as early warnings to accidents. **EWaSAP is the first attempt to expand a widely used systemic hazard analysis approach towards developing reactive and resilient systems**. The benefits of EWaSAP are that:

a) It guides analysts to identify a large number of early warning signs of various types.

b) It is a tool that can be used to justify to others why a perceivable data is truly an early warning sign.

c) It forces analysts and designers to think carefully about the sensors which should be installed within a system, and it should react to a perceivable early warning sign in order to maintain its safety and resilience.

EWaSAP proved to be an effective way of making explicit the early warning signs, which were used tacitly by the staff in everyday operations. This feature can make EWaSAP a useful tool for audits and for the identification and collection of data for leading safety indicator frameworks.

Based on the concepts, relations and constraints of EWaSAP, the SCEWA team defined three graphical domain specific modelling languages which were incorporated into a dedicated open source software editor. The editor allows analysts to use graphical elements in order to conduct hazard and early warning sign analyses in complex systems. The editor can also generate executable computer code that represent the graphical models of the analysis, which can be used for the creation of computer-based early warning systems.

8. References

Bezemer, C.P. and Zaidman, A. (2010). Challenges of Reengineering into Multi-tenant SaaS Applications, Technical Report TUD-SERG-2010-012, Delft University of Technology.

Davison, A., Howard, G., Stevens, M., Callan, P., Kirby, R., Deere, D., Bartram, J. (2003). Water safety plans. World Health Organization, Geneva.

Dokas I.M., Feehan, J., Imran, S. (2013). EWaSAP and Early Warning Sign Identification Approach Based on Systemic Hazard Analysis, Safety Science, Vol 58 pp. 11-26.

Foping F. (2012). A Software as a Service Based Early Warning System for Drinking Water Treatment Plants Safety: Addressing the Quality Assessment and Multi-Tenancy Issues, PhD Thesis, University College Cork.

Foping F. and Dokas, I.M. (2012). 'A Web-Based Early Warning System for Water Treatment Plants Safety', 5th Water Contamination Emergencies Conference: Managing the Threats, 19th to 21st November 2012, Muelheim an der Ruhr, Germany, pp. 22-32.

Foping F. and Dokas, I.M. (2013). 'A SaaS-Based Early Warning Information Fusion System for Critical Infrastructure Safety'. In proceeding of: 10th International ISCRAM Conference May 2013 T. Comes, F. Fieldrich, S. Fortier, J. Geldermann and T. Muller, At Baden-Baden, Germany, pp. 156-165.

Irish Environmental Protection Agency. (2011). The provision and quality of drinking water in Ireland a report for the years 2008 – 2009. Online at http://www.epa.ie/downloads/pubs/water/drinking/ DrinkingWater_web.pdf.

Leveson, N.G. (2004). A new accident model for engineering safer systems. Safety Science, 42, 237-270.

Leveson, N.G. (2011). Engineering a Safer World: Systems Thinking Applied to Safety. MIT Press.

Imran S. (2012). Hazard and Early Warning Analysis Based on Domain Specific Modeling Technologies, PhD Thesis, University College Cork.

Turner, M., Budgen, D. & Brereton, P. (2003). Turning software into a service*, IEEEComputer Society,* 36,10, 38–44.

U.S. Environmental Protection Agency. (2005). Overview of Event Detection Systems for Water Sentinel, Report of U.S. Environmental Protection Agency Water Security Division Ariel Rios Building, EPA 817-D-05-001.

Woodcock, K. (2013). Model of safety inspection, Safety Science, 62, 145-156.

Woods, D.D. (2009). Escaping failures of foresight, Safety Science, 47(4), 498-501.

Acronyms and Abbreviations

AI	Artificial Intelligence
AML	Analysis Modelling Language
CPD	Continuous Professional Development
CSML	Control Structure Modelling Language
DERP	Developing Environmental Researcher Potential
DWTP	Drinking Water Treatment Plant
DSML	Domain Specific Modelling
EPA	Environmental Protection Agency
EWaSAP	Early Warning Sign Analysis based on STPA
HSE	Health Service Executive
ICAML	Inadequate Control Action Modelling Language
MIT	Massachusetts Institute of Technology
RAL	Remedial Action List
SaaS	Software as a Service
SCEWA	Supporting the Concept of Early Warning Analysis
SMS	Safety Management System
SQL	Standardised Query Language
STPA	Systems Theoretic Process Analysis
WSA	Water Service Authority

Appendix 1 - Outputs of the SCEWA Project

Journal Papers

Dokas I.M., Feehan, J., Imran, S. (2013). EWaSAP and Early Warning Sign Identification Approach Based on Systemic Hazard Analysis, **Safety Science**, Vol 58 pp. 11-26.

Foping, F.S., Dokas, I.M., Feehan, J., Imran, S. (2010). An Improved Schema-Sharing Technique for a Software as a Service Application to Enhance Drinking Water Safety, **Journal of Information Security Research** (JISR), 1(1), pp 1-10.

Imran, S., Foping, F.S., Feehan, J., Dokas, I.M. (2010). Domain Specific Modelling Language for Early Warning System: Using IDEF0 for Domain Analysis, **International Journal of Computer Science Issues**, Volume 7, Issue 5, pp 10-17.

Book Chapter

Dokas, I.M., Feehan, J., Fortier, S., Foping, F., Imran, S. (2011). Towards Supporting State Agencies in Providing Early Warning Services: A Case Study from Ireland: Examining **Global and Regional Responses to Disasters** (DeMond Miller and Jason Rivera Eds.) **,** pp. 291-327. CRC Press

International Conference Papers

Foping F. and Dokas, I.M. (2013). *'A SaaS-Based Early Warning Information Fusion System for Critical Infrastructure Safety'*, **ISCRAM2013: The 10th International Conference on Information Systems for Crisis Response and Management**, 12-15 May 2013 Baden-Baden, Germany, pp. 156 - 165.

Foping F. and Dokas, I.M. (2012). *'A Web Based Early Warning System for Water Treatment Plants Safety'*, **5th Water Contamination Emergencies Conference**, 19th to 21st November 2012, Muelheim an der Ruhr, Germany.

Foping F. and Dokas, I.M. (2011). 'Securing a Critical Web Application', **23rd European Conference Forum Bauinformatik**, University College Cork, 12 -14 September 2011, (http://zuse.ucc.ie/forumbau2011/papers/34.pdf) ISBN 978 - 1 - 9066 - 42 - 38

Foping, F., Dokas, I.M., Feehan, J., Imran, S. (2009). "*A New Hybrid Schema-Sharing Technique for Multitenant Applications*", **4th IEEE International Conference on Digital Information Management**, University of Michigan, 1-4 November. Proceedings in CD

Foping, F., Dokas, I.M., Feehan, J. (2009). "*On Using Software as a Service to Deploy an Early Warning Service*", In Bobby Granville, Zoran Majkic, Chunping Li (Eds.), **International Conference on Enterprise Information Systems and Web Technologies**, Orlando, FL, USA. ISBN: 978-1-60651-010-0, pp. 161-168

Dokas, I.M., Wallace, R.J., Marinescu, R., Imran, S. and Foping, F. (2009). "*Towards a Novel Early Warning Service for State Agencies: A Feasibility Study"*, In I.N. Athanasiadis et al. (Eds) Environmental Science and Engineering**, Information Technologies in Environmental Engineering (ITEE' 2009),** pp 162 - 175, ISBN: 978-3-540-88350-0

Peer Reviewed Paper in International Workshop

Imran, S., Dokas, I.M., Feehan, J., Foping, F. (2010). A New Application of Domain Specific Modelling Towards Implementing an Early Warning Service, **Proceedings of MDA & MTDD 2010, 2nd International Workshop on Model Driven Architecture and Modelling Theory-Driven Development in Conjaction with ENASE** , 22-24 July Greece.

Short Journal Papers

Imran, S. (2010). Early warning system for safe drinking water: A domain specific modelling approach, **The Boolean**, Volume 1, Pages 86 - 88.

Foping, F. (2010). A web-based early warning service to monitor drinking-water treatment plant operations, **The Boolean**, Volume 1, Pages 69 - 73.

Poster Papers

Imran, S., Dokas, I.M., Feehan, J., Fopping, F. (2010). Towards Domain Specific Modeling Approach in Early Warning Systems, 7th **International Conference on Information Systems for Crisis Response and Management**, Proceedings in CD, May 2-5 Seattle USA

Technical Reports

Dokas, I.M. (2009). Safety Approaches in Water Utilities and Systems Safety Engineering: A Comparison , Cork Constraint Computation Centre Technical Report - TR 02-09-01-01, Cork 2009.

Dokas, I.M. (2008). Early Warning Systems: Views and Application Domains, A report submitted to the Irish Environmental Protection Agency in conformity with the specifications of the research project Supporting the Concept of Early Warning Analysis – SCEWA, (Submitted on July 2008)

Invited Talks

Dr. Dokas was invited to present various aspects of the research work of this project to the following venues:

2012: The Intel Ireland Research Conference 2012, Dublin, Ireland. Talk Title: 'A SaaS-Based Early Warning System for Water Treatment Plant Safety.'

2011: ISCRAM Summer School 2011, Tilburg, The Netherlands. Talk Title: 'Systems Safety and Early Warning Systems'.

2010: Irish EPA National Research Conference, Dublin Ireland. Talk Title: 'Developing an Early Warning System for Drinking Water Treatment Plants'.

2010: S4 ENVISA 2010 Colloquium on Spatio-Temporal Data Analysis, Cork Ireland. Talk Title: 'The SCEWA Project: A Short Description'.

2010: Dalle Molle Institute for Artificial Intelligence (IDSIA), Lugano, Switzerland. Talk Title: 'Sociotechnical Early Warning Systems'.

2009: HSE – Irish Health Service Executive, Population Health Water Group, Health Protection Surveillance Centre, 25-27 Middle Gardiner Street, Dublin Ireland. Talk Title: 'Towards an Early Warning Safety Management System for Water Treatment Plants'.

2009: IBM Innovation Centre Mulhuddart Dublin Ireland. Talk Title: 'Early Warning Services for Complex Socio-Technical Systems'.

2009: IBM Innovation Centre Mulhuddart Dublin Ireland. Talk Title: 'Towards Development of an Early Warning Service for Water Treatment Plants'.

2008: Tyndall Institute, Cork Ireland. Talk Title: 'Early Warning Systems for Water Treatment Plants: Analysis and Design Issues'.

Invention Disclosure

Dokas, I.M., Foping, F., Imran, S., Feehan, J. "A Web-Based Early Warning System For Water Treatment Plants", University College Cork, Ireland, IDF - UCC 10-52**,** 2010

Special Session Organisers in International Conferences

Dr. Dokas was among the organisers of the following special sessions in International Conferences:

- Early Warning and Alert Systems, 8th International Conference on Information Systems for Crisis Response and Management, Lisbon Portugal, May 8 -11, 2011.
- Advanced Information Technologies for Crisis and Disaster Management, 5th International Conference on Information Systems for Crisis Response and Management, Washington DC, USA May 4-7 2008.

PhD Thesis Submissions

Two PhD diplomas were awarded to members of the SCEWA team.

Foping, F. (2012). A Software as a Service Based Early Warning System for Drinking Water Treatment Plants Safety: Addressing the Quality Assessment and Multi-Tenancy Issues, PhD Thesis, University College Cork.

Imran, S. (2012). Hazard and Early Warning Analysis Based on Domain Specific Modelling Technologies, PhD Thesis, University College Cork.

Media

Project web site URL: http://4c.ucc.ie/scewa/

Newspaper: Franclin Foping and the SCEWA project were mentioned on the EVENING ECHO on Monday, March 30th 2009.

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil, Pobal agus Rialtais Áitiúil.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail;
- scardadh dramhuisce;
- dumpáil mara.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

Science, Technology, Research and Innovation for the Environment (STRIVE) 2007-2013

The Science, Technology, Research and Innovation for the Environment (STRIVE) programme covers the period 2007 to 2013.

The programme comprises three key measures: Sustainable Development, Cleaner Production and Environmental Technologies, and A Healthy Environment; together with two supporting measures: EPA Environmental Research Centre (ERC) and Capacity & Capability Building. The seven principal thematic areas for the programme are Climate Change; Waste, Resource Management and Chemicals; Water Quality and the Aquatic Environment; Air Quality, Atmospheric Deposition and Noise; Impacts on Biodiversity; Soils and Land-use; and Socio-economic Considerations. In addition, other emerging issues will be addressed as the need arises.

The funding for the programme (approximately €100 million) comes from the Environmental Research Sub-Programme of the National Development Plan (NDP), the Inter-Departmental Committee for the Strategy for Science, Technology and Innovation (IDC-SSTI); and EPA core funding and co-funding by economic sectors.

The EPA has a statutory role to co-ordinate environmental research in Ireland and is organising and administering the STRIVE programme on behalf of the Department of the Environment, Heritage and Local Government.

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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SSTI Strategy for Science, Technology and Innovation

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government