American Journal of Research, Education and Development

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ISSN 2471-9986

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American Journal of
Research, Education and Development

IMPRESSUM

American Journal of Research, Education and Development
ISSN: 2471-9986

Publisher: DEVLART LLC
250 Camelback Ridge Ave. Henderson, NV 89012
red@devlart.hu

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Fire protection rating of building geotextiles based on oxygen index

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Abstract

The plastic industry was developed significant in the last decades. The application of plastics are increasing, because of this it is a high-risk factor. The characterization of the behavior of plastics while being on fire is of great importance for the practical use of plastic materials. Toxic gases arose during combustion of plastics, that's dangerous for people and environment. Polyester (PES) is one of the most important synthetic polymers. Subject of my examination is then on woven textiles. They are widely used in many fields such as flat roof insulation. Conversely, it has various disadvantages such as highly flammable combined with dripping, smoking, shrinking effect. For these reasons, it is necessary to improve the anti-dripping and fire retardant properties of textiles, that used in buildings. The flue gas composition, the combustion temperature affect the survival chances in case of fire. The aim is, that analyze flame retardant properties of the polyester geotextiles with LOI. The method provides a classification of the burning behavior.

Keywords: fire protection, polymers, polyester, geotextile, flammability, self-sustaining combustion, non-woven geotextile

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Introduction

Polyester is one of the most important synthetic polymers. It is widely used in the construction, textile and automotive industries. By itself and as a mixture, it can be used as a raw material for protective clothing, everyday clothing products, bedding, upholstery, and floor coverings [1].

Non-woven polyester textiles, including geotextiles, have a wide range of uses, including in the construction industry as a separating fabric during the insulation of flat roofs and under roofing. Roofs are always a particularly fire-prone zone of a building. Polyesters are flammable materials characterized by dripping, smoke generation and shrinkage when burned. [2]. During a fire, the composition of the flue gases, the ignition and flame propagation time of the material determine the escape time. Their use is made possible with flame retardants, which can be used to delay ignition. This is why it is necessary to qualify the flame retardant effects of textiles used in the construction industry, in residential buildings - or in any area. There are standards and regulations for their qualification. The aim of our study is to classify the flame retardancy of polyester textiles using a conventional and an unconventional qualification parameter called by specifying an oxygen index. We asked as a question whether the test according to EN ISO 11925-2-2002 included in the requirements of EN 13 501-1 for building materials is sufficient. Because according to the EN ISO 13501-1 requirements standard, B, C, D are the classifications if, with an exposure time of 30 seconds, the vertical flame spread cannot exceed 150 mm within 60 seconds. "E" classification if this exceeds 20 seconds, 15 sec ignition time, "F" classification if it fulfills this within 20 sec with an ignition time of 15 sec. (MSZ EN 13 501-1) [3].

Polyester as a combustible material

Combustion is preceded by heating to the decomposition temperature. This leads to the breaking of the polymer chains, during which gas-phase cracking products are also released. The oxidation of combustible gases is an exothermic reaction, which, if it exceeds the endothermic decomposition reaction, leads to the formation of a self-sustaining flame. [4] During pyrolysis (600-900 oC) under oxidative conditions, a multi-component recyclable mixture can be obtained.

Combustibility parameters typical of polyesters.[5]

Tg (softening point): 85ºC

Tm (melting point): 255ºC

Tp (initial temperature of pyrolysis/decomposition, 420–427ºC

Tc (ignition point) 480ºC

Oxygen index (LOI): 20 – 21

The combustion of a polymer is influenced by several parameters, but from the point of view of practical use, the effect of flame retardant additives is the most important. The task of the flame retardant is primarily to prevent the spread of an established fire, but at least to delay the combustion process as much as possible [6].

According to the recommendation of M.NEISIUST AND COLLEAGUES [7], the best flame retardants for polyesters are halogenated compounds, which exert their effect in the vapor phase. Halogen-containing flame retardants inhibit the chain reaction by binding gas-phase radicals (active H and OH atoms or molecular fragments) formed during the burning of polymers.

Application of construction textiles and relevant regulations

Construction textiles include all textiles and textile-based composites that are used in the creation and repair of buildings and other artefacts such as dams and bridges, including temporary buildings, large tents, inflatable structures, as well as sun protection textiles included as accessories for buildings. Textiles used in architecture are being used in more and more places. Light weight, good mechanical properties, good deformability, flexibility and resistance to chemicals and air pollution make textiles suitable for use in the construction industry. The textile products used in the construction industry fulfill the following functions: [8]

- strengthening of walls and facades
- concrete reinforcement, plaster reinforcement
- roof insulation, waterproofing
- heat and sound insulation
- fire prevention

Significant weight savings can be achieved by using textile reinforcement. This is not only based on the lower specific gravity of the textile than the iron, but also the wall thickness can be reduced, as there is no need for a layer of concrete used to protect the iron against rusting. Lightweight, thin-walled concrete elements of various shapes can be produced from textile-reinforced concrete, which opens up new applications [8].

Test samples

The tested materials are manufactured by a Hungarian company. made available to us. The factory characteristics of the polyester geotextile samples are presented in Table No. 1.

Table 1. our test samples and their characteristics

Pattern	Color	Thickness mm	Surface weight g/cm2	Base material	Thermoset surface
G1	white	5	1000	100 % Flame retardant PES	yes
G2	white	1,6	300	100 % Flame retardant PES	yes
G3	white	2,8	300	100 % Flame retardant PES	no
G4	white	1,2	200	100 % Flame retardant PES	yes
G5	white	1,6	300	98 % PES, 2 % PA (poliamid 6)	yes
G6	white		300	100 % Flame retardant PES	yes
G7	white		500	100 % Flame retardant PES	yes
G8	white	5	1000	100 % Flame retardant PES	yes
G9	white		300	100 % PES	no
G10	white	5	1000	100 % PES	no
G11	barna		300	100 % PES	no
G12	fekete	1,38	500	100 % Flame retardant PES	yes

Selection of test methods

1. If the requirement is Euroclass B, C, D, E class (EN 13 501), the measurement of the speed of vertical flame spread must be applied according to MSZ EN ISO 11925-2:2011. (Flammability tests. Flammability of construction products when exposed to direct flame. Part 2). Part of the method for classification into classes B, C, D, E, B fl, C fl, D fl, and E fl.

2. Enter the oxygen index (LOI): ISO 4589-2

Specifying the oxygen index is becoming more and more important and widespread for the qualification of finished products. Larger plastic manufacturing companies no longer only specify the mandatory CE parameters, but also verify the non-flammability and flame-retardant properties by specifying the LOI values, e.g. in the case of electrical cable covers. Its use is also justified by the fact that it is possible to detect hidden flammability properties and thereby compare samples, which are not detected by flame propagation in normal air [9].

Combustion experiments

1. Vertical flame spread (EN ISO 11925)

Before starting the test, 10×10 and 10×30 cm samples were cut from the available sample materials (picture 1). The custom-made samples are fitted into the frame of the testing equipment.

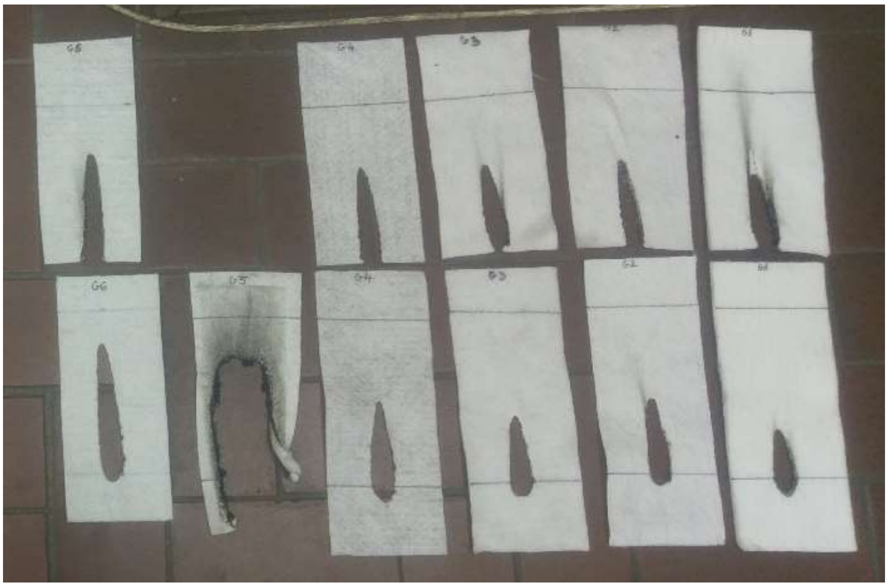
1. Figure: Vertical flame spread speed testing equipment and their combustion in case of wind ignition

2.

We also examine wind ignition and surface ignition on the samples. The flame of the gas burner is set to a flame of 38 mm. The ignition time is 15 seconds for the first time, if the combustion does not last for another 15 seconds. We measure the time when the burn-in (degree of damage) reaches the first and second marks at a distance of 150 mm (picture 2). If the combustion stops before the second signal is reached, the corresponding burn-in length and elapsed time are measured. If the burn does not reach the first sign, the sample is certified as self-extinguishing.

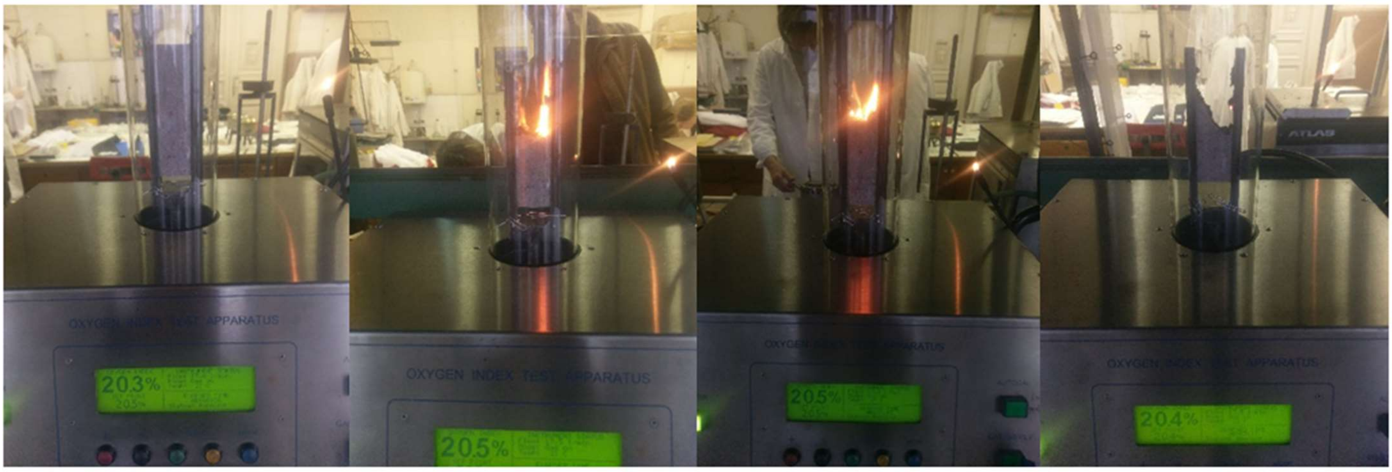
Visible results of tests

Burn-throughs, burn-in length, and melting and dripping are the parameters that must be recorded according to the standard, that is, all the phenomena shown by the damage of a sample. Thus, a quick comparison is easily possible.



3. Figure: G1 - G6 Damage to samples after wind and surface ignition

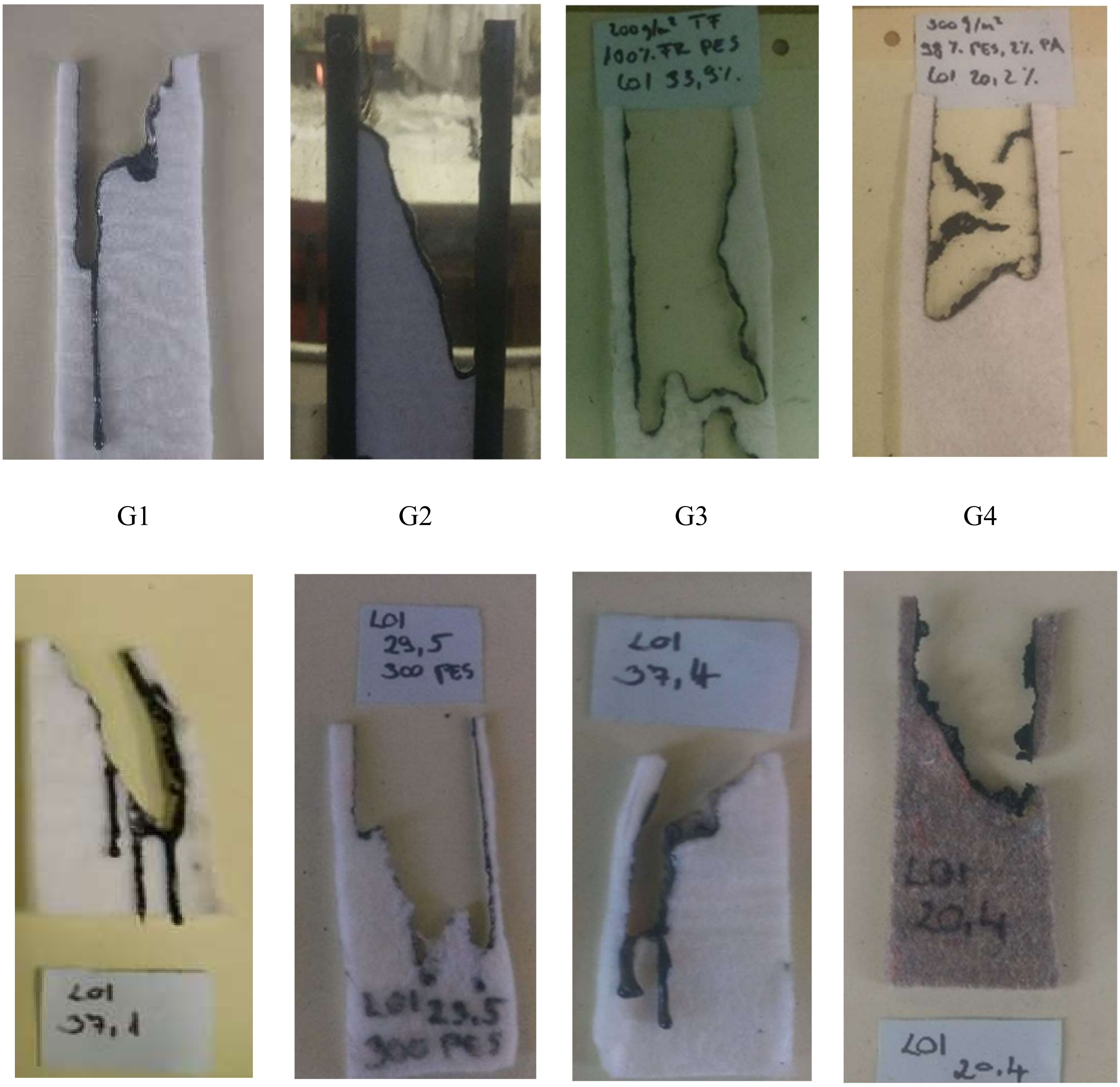
4. *Figure: Damage to samples G7-G12 after wind and surface ignition*



5. *Figure: The steps of the G11 sample test*

Picture 4 shows the process of the oxygen index test of sample G11, with the results of the measurement in picture 5.

6. Figure: Damage of samples G8 and G11 burned in different oxygen contents



G1 G2 G3 G4

G5 G6 G7 G8

7. *Figure: Damage of samples burned in different oxygen contents*

Oxygen index (LOI) test results

The results of the firings are summarized in Table 2, so you can quickly see the relationship between flame spread, melting phenomena and LOI.

During the tests, we observed the following. Except for G5 and G9, they all met the flame spread. Samples G1-G4, G6-G8 and G10-G12 passed both wind ignition and surface ignition tests. In the case of the G5 and G9 samples, after the wind ignition, the flame reached the 150 mm mark within 20 seconds. Since the sample did not comply with wind firing, surface firing is no longer necessary for these two samples.

Table 2. combustion test results and observations

Sample	Surface mass (g/cm2)	LOI	Smoke formation (visual inspection)	Melt	Wind ignition	Surface ignition	Remark (manufacturer data)
G1	1000	37,1	no	highly melt	appropriate	appropriate	
G2	300	36	no	highly melt	appropriate	megfelel kit	
G3	300	37	no	highly melt	appropriate	appropriate	
G4	200	33,9	no	highly melt	appropriate	appropriate	
G5	300	20,2	highly smoke	no melt	not appropriate	not appropriate	
G6	300	29	no	highly melt	appropriate	appropriate	
G7	500	34,5	no	highly melt	appropriate	appropriate	
G8	1000	37,1			appropriate	appropriate	not FR*
G9	300	29,5			not appropriate	not appropriate	not FR*
G10	1000	37,4			appropriate	appropriate	not FR*
G11	300	20,4	no	highly melt	appropriate	appropriate	
G12	500	21,5	no	highly melt	appropriate	appropriate	

*FR: Flame retardant

But if we look at other properties, only the G1, G8 and G10 samples with an LOI above 37 meet the strictest conditions. It is worth highlighting that their surface density is the highest 1000 g/m2. When testing samples G1-G4 and G6-G10, smoke was not characteristic, but melt was produced. Afterburning is typically caused by the melt. When igniting samples G5, G11 and G12, strong smoke can be experienced, but there is no melt. In the case of some samples, the unevenness of the texture can be detected during the test, the same sample produced different results.

Evaluation of results

As can be seen from the combustion results, there is no clear correlation between the physical and chemical composition (FR) of the material. This complicated matrix parameter can be made suitable by combustion in an increased oxygen content, so that we can more safely specify the flammability behavior of a material. However, we do not consider them to be fire-safe under actual burning conditions. Polyesters with an LOI of 34-37 (solid, with a surface weight of 1000 g/m2, self-extinguishing combustion) can already be safely used as building materials.

The self-extinguishing, low flame spread does not yet provide sufficient information, specifying the oxygen index means complete safety. The "small flame test" is actually a small flame effect, which does not show the actual heat load in the event of a fire. This can be replaced by burning in an increased oxygen content.

The LOI values of the samples giving highly sooty smoke (G5, 11,12) are below 30. Polyesters with a LOI of 34-37 (solid, with a Areal weight of 1000 g / m2, self-extinguishing combustion) canal ready be safely used as building materials. A self-extinguishing, low flame spread is not yet sufficient information, giving an oxygen index means complete safety. A sample with a low surfacedensity (200 g / m2) can also be flame retardant after appropriate treatment. Ourstudies show that the burning behavior of PES-based non wovens is shaped by both surface density and burn delay. Our research can also be a good basis for other series of publications on similar topics.

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Possible Applications of Intelligent Radiation Detectors

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Nowadays, intelligent detectors are more often used in everyday life applications. This trend can also be observed in the field of radiation measurement. For several types of detectors, the term "intelligent" has been added to their name. But what makes a detector intelligent? This paper is looking for an answer to this question. An intelligent detector is intelligent because it processes, analyses, and interprets the analogue electrical signal that can be extracted from a sensor (e.g., a Geiger-Müller tube, a scintillation crystal) and then runs various algorithms on the raw measurement data to generate useful information. This information supports user decision-making and the work of military and disaster management staff. The combination of different intelligent detectors can form a complete measurement system, which can monitor technologies, facilities or even entire countries. This paper investigates the applicability of intelligent detectors through some examples.

INTRODUCTION

The main purpose of radiation measurement systems is to provide relevant decision support information in the proper format, location and time to the user. In the past, the function of early warning systems was only to visualise the measured value. It was up to the user to decide what to do with the measured result. Most of the instruments used today have built-in alarm functions, e.g. if the measured value exceeds a preset alarm threshold, the detector will start an audible and visual alarm. Future devices will be expected to provide a suggestion on what the user should do in a given alarm situation, reducing the possibility of a malfunction or even an accident caused by a wrong action.

Currently, trained personnel are needed to measure ionising radiation and analyse the data. Intelligent detectors simplify processes to such an extent that a person with minimal background training can perform the measurement with sufficient accuracy. This full paper does not provide a complete picture of the applicability of intelligent detectors, but only a summary of the results of a single PhD thesis [1]. The PhD thesis investigates the relevance of intelligent detectors for military and disaster management purposes.

ENVIRONMENTAL MONITORING SYSTEMS

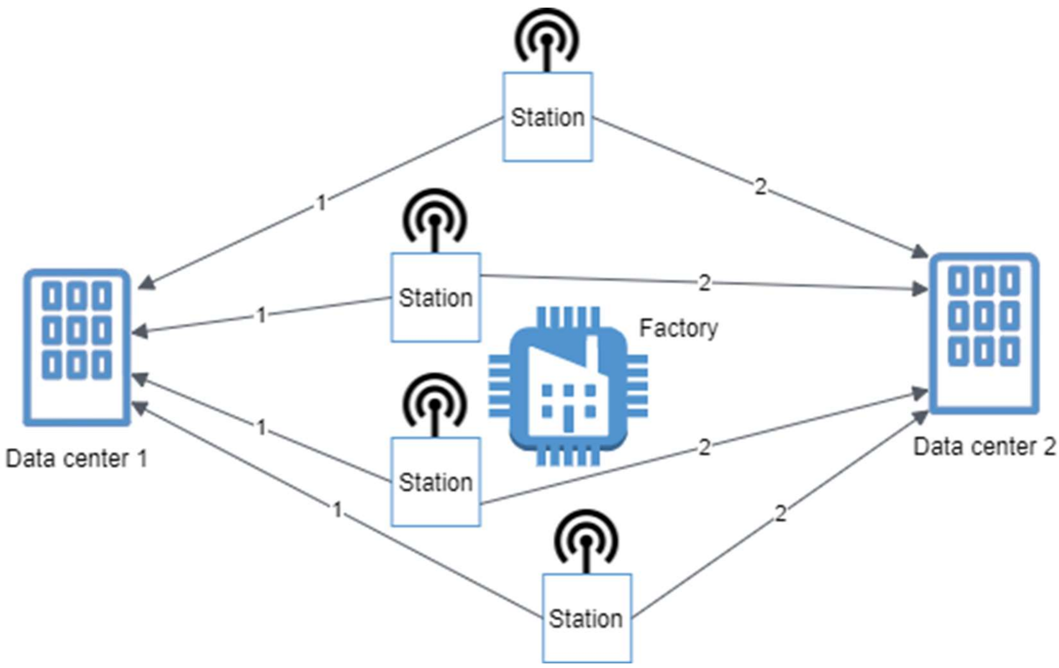
Intelligent detectors are ideal for building ambient background radiation monitoring systems. In this configuration, the detector is connected to a telemetry network. To set up the network, the necessary components have to be selected and the tasks of each component have to be predefined.

Telemetry networks based on intelligent detectors allow the processing of the measured results at the point of measurement and, thanks to modern telecommunication technology, the data can be made available in digital form anywhere in the world.

A telemetry network consists of the following elements: monitoring stations, communication infrastructure, data centres, data transmission infrastructure.

The simplest monitoring system requires a radiation detector and a display. If the radiation monitoring system is to continuously monitor a site and the radiation measurement and display are to be implemented at two remote locations, a data link between the detector and the display unit is required. The data transmission can be of different types, usually based on some standard communication interface. In case a large number of monitoring stations have to be connected, it is advisable to choose a communication interface that allows the connection of stations without restrictions and the transmission of data over long distances. Ethernet-based data transmission is the most suitable technology for this task and can be used over wired and wireless data networks. Connecting stations via cables is costly, so wireless (radio) solutions are most often integrated. Choosing the right radio transmission is of crucial importance. Although 3G/4G/5G technologies used in traditional civilian life are widely available, they are not guaranteed to work in an emergency [2]. There are data transmission technologies that can be used specifically for disaster management organisations (e.g. TETRA). Such systems can be used to operate monitoring systems with a high level of security in an emergency situation [3].

For high availability systems, it is necessary that the system has multiple data centres (data collectors, displays). In the case of multiple data centers, synchronisation of data and acknowledgement of events raises a number of technical issues. The architecture of a system with multiple data centers is shown in Figure 1.



1. *Figure: The architecture of a telemetry network with two data centers. Source:* [4]

Monitoring stations usually have local data storage capacity. This capability enables the storage of measured data even in case of a failure at the communication channel or at a higher IT system level. The data stored at the station is sent after the communication channel is re-established between the data center and the station. In more advanced systems, alarm data packets precede normal measurement data packets [4].

One of the most important elements of the telemetry network is the detector installed at the station which provides measurement data. An intelligent detector consists of the following components:

- A sensor provides an analog electrical signal proportional to the environmental parameter.

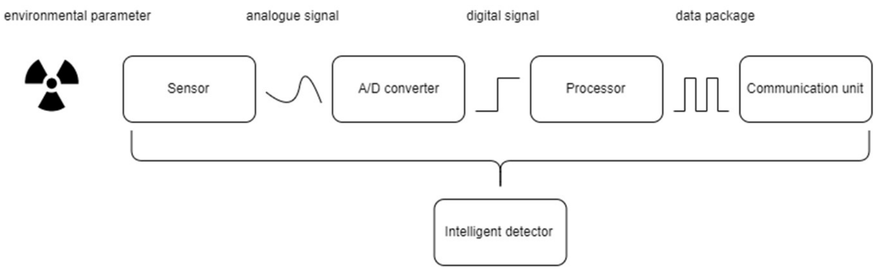
- An analog/digital (A/D) converter converts the analog signal from the sensor into digital form, performing the necessary signal matching and conditioning tasks.

- Microcontroller processes the digital signals and intervenes if necessary, e.g.: performs self-diagnosis at given intervals and calibrates the sensor, in order to ensure that the measured result is accurate and reliable in all cases (e.g. at high and low temperatures). The microcontroller can perform further data processing and automatic evaluation, such as isotope identification.

- With the help of a digital/analog (D/A) converter, the microcontroller can intervene in the analog signal processing, in order to make the measurement more accurate.

- A communication interface formats and transmits the digitized measured values to the higher IT system according to standard protocols.

The connection of the components is shown in Figure 2.



2. *Figure: General structure of an intelligent detector. Source:* [4]

Intelligent detectors operating on the scintillation principle are often used in monitoring systems. However, most scintillation detectors are not suitable for military and disaster management applications because they are sensitive to changes in environmental parameters. Changes in temperature, humidity, vibration and external electromagnetic radiation all significantly affected the measured results.

There are several possible solutions to eliminate these problematic factors. For example, a properly chosen enclosure can prevent external light from interfering with the measurement. Mechanical absorbers can be used to make the detector resistant to mechanical vibration. The effect of external electromagnetic radiation can be eliminated by using special circuit solutions built into the detector and properly designed shielding and grounding. Temperature variations cause significant errors in the measurement results, which is why it is necessary to use temperature compensation in the scintillation detector. The thermal insulation of the detector protects the detector from the effects of sudden temperature changes.

If a detector equipped with a NaI(Tl) scintillator is placed at a high dose level, above a certain dose rate the detector will not be able to process the signal and will give false readings for a certain time after irradiation. If the detector has to be prepared for such a case, it is advisable to choose specific scintillator material or to switch from pulse processing to anode current measurement [5].

RADIATION PORTAL MONITOR SYSTEMS

Scintillation detectors have been used in radiation portal monitor applications for decades. The role of intelligent detectors in such systems is to improve the quality of the information provided by the system in case of detection of hidden radioactive material.

If a radiation portal monitor is not sensitive enough or does not work with the right algorithm, the system will allow contamination to pass through the checkpoint. A set of criteria can help the builders of a radiation portal monitor system to apply the most appropriate assembly, configuration and operational procedure that can improve the efficiency of detection of hidden radioactive materials.

Intelligent detectors allow the implementation of algorithms for specific tasks. For example, such an algorithm can help the system to determine whether the radiation that triggers the alarm is from a natural or artificial source [6].

Proven security solutions for the physical protection of radioactive sources have been in place for a long time. Establishments using radiation sources usually have radiation detectors installed. By implementing the algorithm used in radiation portal monitors, the existing radiation detection unit can be made capable of providing additional information to the security system in case of source relocation. This method can be used to increase the level of security at sites where radiation sources are used and stored without the need for a new device.

The algorithm accepts certain predefined measurement ranges as operating or storage states and generates a warning signal in all other cases. A measurement outside of pre-determined ranges that is not allowed may indicate a malfunction or illegal removal of the source [7]. The normal and alarm ranges of the radiation portal monitor algorithm are illustrated in Figure 3.

3. *Figure: Intelligent detector operation in source protection mode. Source:* [7]

ON-FOOT RADIATION RECONNAISSANCE SYSTEMS

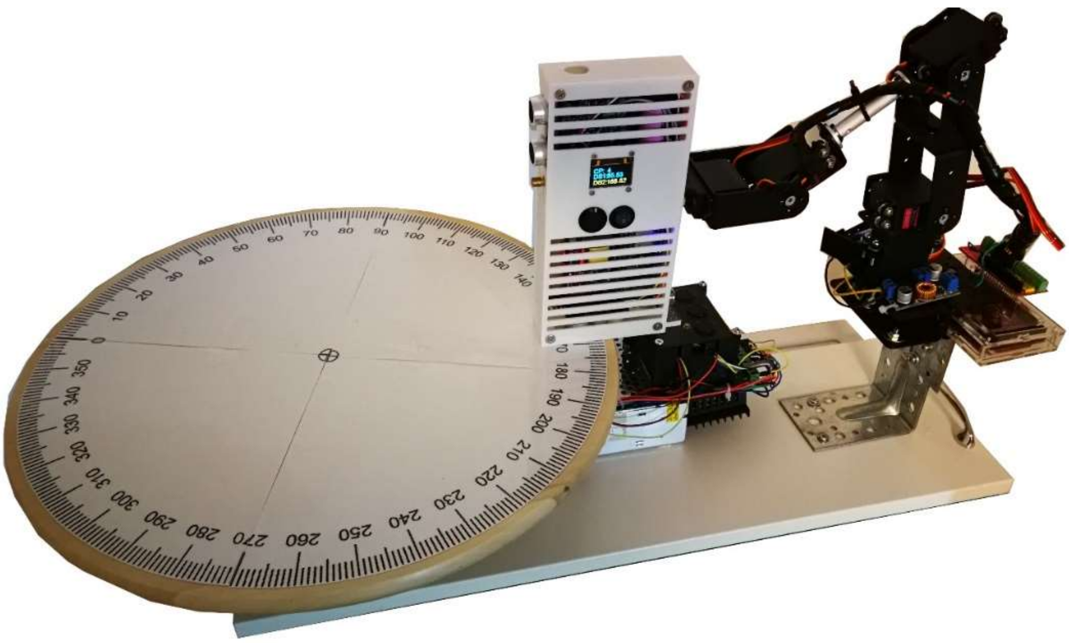
Intelligent detectors are often used in on-foot RADIATION RECONNAISSANCE tasks. It has been experienced that in several cases when performing a search task for hidden or lost orphan radiation sources, the radiation detection instruments were either not sensitive enough or did not have the necessary directional dependence to help locate the sources. Based on many tests a so-called "rotation" search method, and a hardware add-on unit (lead collimator ring) and a software search algorithm gave the best results for finding radioactive sources. These additions allow the detector to find the source as quickly as possible, even if there are several other hidden sources nearby.

Intelligent detectors can also significantly improve the inspection processes of radioactive shipments. At present, only the outer shell of shipments is checked using dose rate meters and the travel documents are checked according to formal requirements. It is relatively easy to bypass this control by hiding artificial radioactive sources in a shipment containing large quantities of natural radioactive material (e.g. ceramics, fertilisers) [8].

As most traffic controls it is not allowed the opening of the shipment, only non-destructive external measurement solutions are acceptable.

A rudimentary solution to this problem can be a simple phone application, which calculates the radiation level caused by the activity of the source in the travel documents at the wall of the container, which can then be verified with a measuring instrument.

In addition to the radiation level measured on the outer wall of the container, there are other measurable parameters: mass, height and external dimensions. Combining these parameters with radiation level data can help to estimate the activity of the source being transported. This method can be used to check the shipment without information from the travel documents. To verify the theory, an experimental prototype has been created and is shown in Figure 4. The prototype consists of a rotating table and a robotic arm on which a radiation measurement instrument is mounted. When the container is placed in the center of the rotating table, the radiation meter automatically measures around the container and provide results [9].

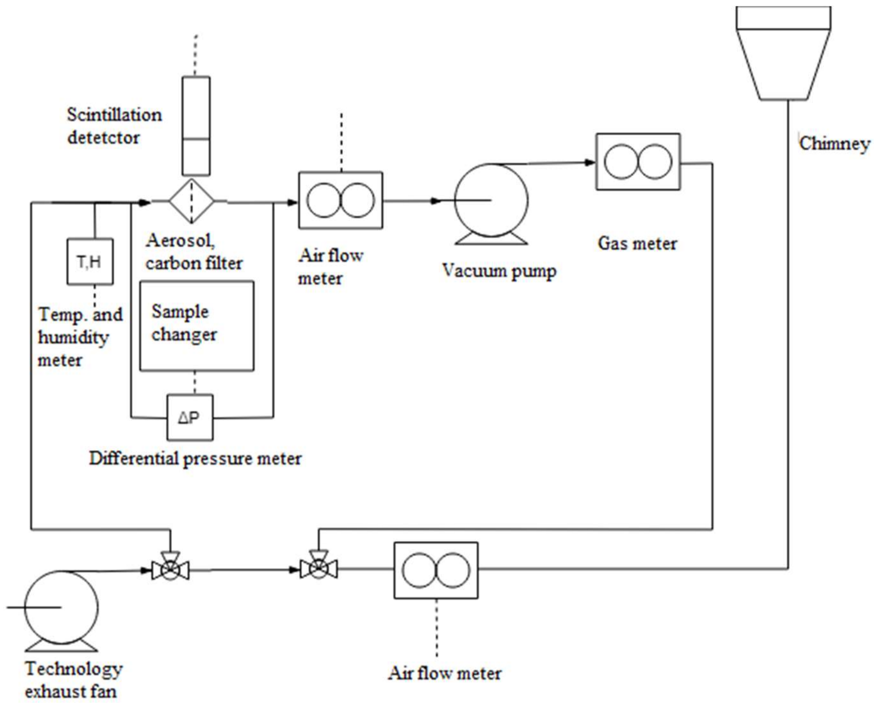


4. *Figure: Container Inspection Prototype. Source:* [9]

EMISSION CONTROL SYSTEMS

Some activities involving certain radiological materials emit airborne contaminants into the environment. Measurement of emissions is essential to demonstrate that the amount of radioactive material leaving the technology or stacks is below the maximum permitted emission level for the period. Several methods for stack monitoring are possible, but the most appropriate solution for the technology must be found, taking into account several aspects. An important consideration in the selection of a possible solution is that the measured result should not be affected by the radiation work carried out near the measuring system. Intelligent detectors can be integrated into such systems, for example in the arrangement shown in Figure 5, where the detector measures the contamination captured by a filter in the sampled air flow. In the event of filter clogging, rupture or high radiation levels, the detector can initiate automatic filter replacement.

Intelligent detectors can measure and quantify emissions, either directly in the air piping system in real time or after sampling with post-sampling evaluation [10].



5. *Figure: Schematic diagram of an online emission monitoring system with combined aerosol, elemental, organic, iodine and noble gas measurement. Source:* [10]

SUMMARY

Intelligent detectors have a very wide range of applications. They can easily be used to build a telemetry, radiation portal monitor, reconnaissance or even emission control system.

The applications listed in this paper are only a small sample of the potential uses of intelligent detectors.

Intelligent detectors can help make our work easier, more accurate and safer.

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Examining the decisions of firefighting managers in the management of remediation operations

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Abstract

The effectiveness of field remediation depends on the decision of the leaders of operation, which are basically determined by their personal preparedness. As a result, one of the biggest risk factors for successful remediation is the outcome of the decision of officers in charge. Our security environment is constantly changing, and the number of disasters is increasing, therefore the requirements for officers in charge are increasing. Therefore it is an important task is to examine the decisions of officers in charge, develop decision-making skills, and facilitate the application of decision support systems in the field of operation management.

In this paper theoretical and practical opportunities that support efficient and effective decision making (thus rescue management) are presented, focusing on practical applications. In addition to supporting decision-making, it is also necessary to develop decision-making skills to meet the challenges of continuous changes in the environment. The aim of our research is to increase the effectiveness of operation management decisions.

Keywords: remediation operation, decision of officer in charge, decision support, development of decision-making skills

Introduction

One of the most important elements of managerial activity is decision-making. When solving tasks, the goal is mostly to achieve some kind of optimum. We are looking for the result that is most favorable in the given circumstances. [1] Almost all management decisions are made under risk conditions. [2] This is particularly true for persons managing remediation operations. Persons in senior positions make a number of decisions in their daily activities. There are decisions that are preceded by a number of preparatory, supportive activities, and there are also management decisions that must be made in real time, with a tight time limit. In this case, there is no adequate time for preparing a decision, examining individual options, as well as analyzing possible outcomes, therefore, these decisions are greatly influenced by the professionalism of the decision maker, in addition, his personal experience, skills. There are programmable decisions when the decision situation is often repeated. In such cases, the decision-making procedure may be regulated in advance. However, non-programmable decisions are also possible if the decision situation is unique and complex, so the decision-making process largely depends on the decision-maker's subjective judgment, knowledge and prior experience. In the case of real-time decisions, the identification of the decision situation is an important phase of decision-making, as the consequences of hasty or even delayed decisions are of paramount importance for the management of the event. Such decisions are also taken by the persons in charge of remediation operations, who are constantly under pressure to make decisions and in most cases have only a limited amount of minutes to make individual decisions. For these reasons, it is an important task to examine the decision-making process and the decisions made on a scientific basis. Management decisions are made in a wide spectrum, the examination of which would exceed the scope limits of this work of writing, so we will only examine the decision-making process of the persons managing the remediation operations in our article. In addition to the decision-making process, our goal is also to examine the preparedness and decision-making skills of decision-makers, and to explore their development opportunities during our research.

Analysis of the elements of the decision process

A complex task always consists of several subtasks:

- individual tasks can be performed sequentially,

- after the completion of each task, several activities can be started at the same time, they can flow in parallel. All subtasks and sub-activities must be combined in such a way that they actually follow each other, or perhaps take place independently of each other in parallel. [1]

The decision, driving function, selection of a single option from the set of considered variants of action, in order to achieve the specified goal. To make an informed decision, you need to know "what" and "what we want to achieve", as well as how to compare existing knowledge and information and, based on this, to select the necessary actions to be taken. All this affects his decision-making process, his algorithm. A decision can and should be taken when alternatives to action exist in terms of purpose, methods of implementation, or both. The decision-maker must have freedom of movement, i.e. a relative degree of freedom in the design and qualification of alternatives, the possibility of making a comparative assessment of alternatives and information on the criterion of choice. [3] The outcome of management decisions is greatly influenced by the preparation of decisions. Normally, the preparation of strategic management decisions is carried out by decision management, examining all the influencing factors. [4] The decision-making process may have several participants who are involved in the preparation of decisions, and even a group decision can be made, but at the end of the process it is always the individual decision-maker. The works are managed by a person, the firefighter/rescue manager, who has the authority to make decisions to carry out each task. Damage elimination is characterized by topdown decision-making, according to which decisions are made by the firefighter/rescue manager at the top level of the organizational hierarchy, which takes the form of direct instructions at the level of implementation. The operation management system is therefore closed from a decision-making point of view, decisions are made on the basis of the professional skills, acquired knowledge and practical experience of the rescue manager. [5]

During a remediation, the field manager has to make many decisions that form a series of decisions, from which it follows that the impact and outcome of each decision can greatly influence the next decision or the entire remediation activity. Thus, it can be concluded that the decision is a process activity, the decision act itself is preceded by a longer or shorter decision preparation. Problem solving is nothing more than a creative process aimed at resolving a situation in search of an optimal solution. If the decision is defined as a process activity, then that process can also be placed in a system, since the application of the system approach facilitates science-based studies. An important element of the decision-making process belonging to the system approach is the preparation of the decision, the decision maker himself, the decision made by him, as well as the assessment of the consequences. In the case of decisions taken in the course of remediation or on the ground, the examination of the consequences of the decisions can only be carried out after the liquidation of the damage event.

The elements of the decision-making process, which are analyzed in detail below, are illustrated in the following figure.

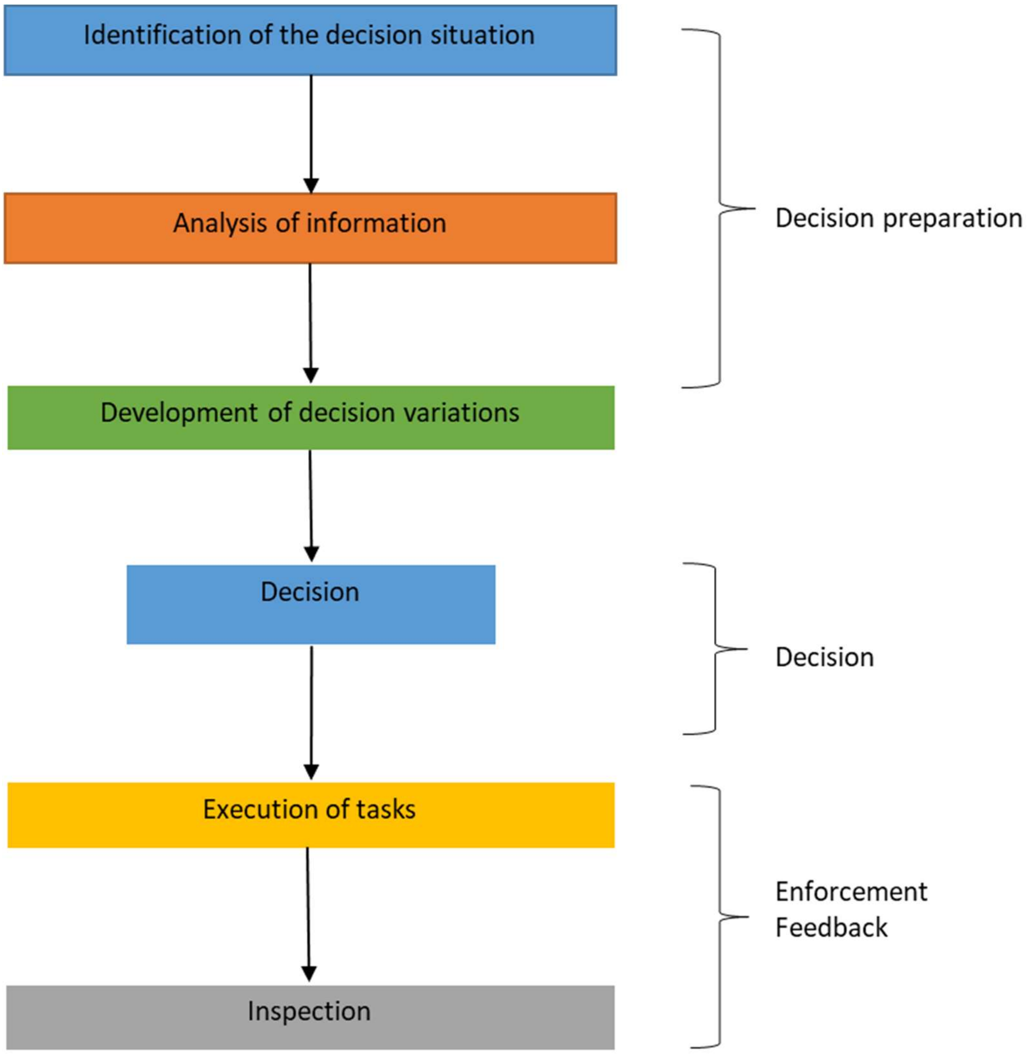

Figure 1 : Elements of the decision-making process (based on source: [6], with additions by the authors)

The identification of the decision situation is a very important stage in the decision-making process, since the timing of the decision, the perception of the situation when it becomes necessary to make a decision, cannot be accidental. Since a decision made in real time at a damage site requires serious professionalism, creativity and intuition, it is often the case that managers who are entitled to make decisions do not make decisions at the right time. After identifying the situation, recognizing and perceiving the situation, the recognition phase means starting a concrete action process. The next step is to analyze the available information, which is most often obtained by the decision maker during field reconnaissance, and then organizes and analyzes it in preparation for the decision. It then reviews the emerging solution variants, from which it selects the most suitable one in the short time available to it, evaluates it quickly and makes a decision. The implementation of the decision, the implementation of the task itself must be controlled. On the basis of the experience of the audit, if necessary, a new decision preparation, decision and implementation should be carried out(6). The person of the decision maker is therefore a key element of the process. In order to examine management decision-making at a deeper level, it is also necessary to deal with the dynamic perception of the decision-making process. The following diagram shows the phases of management decision-making.

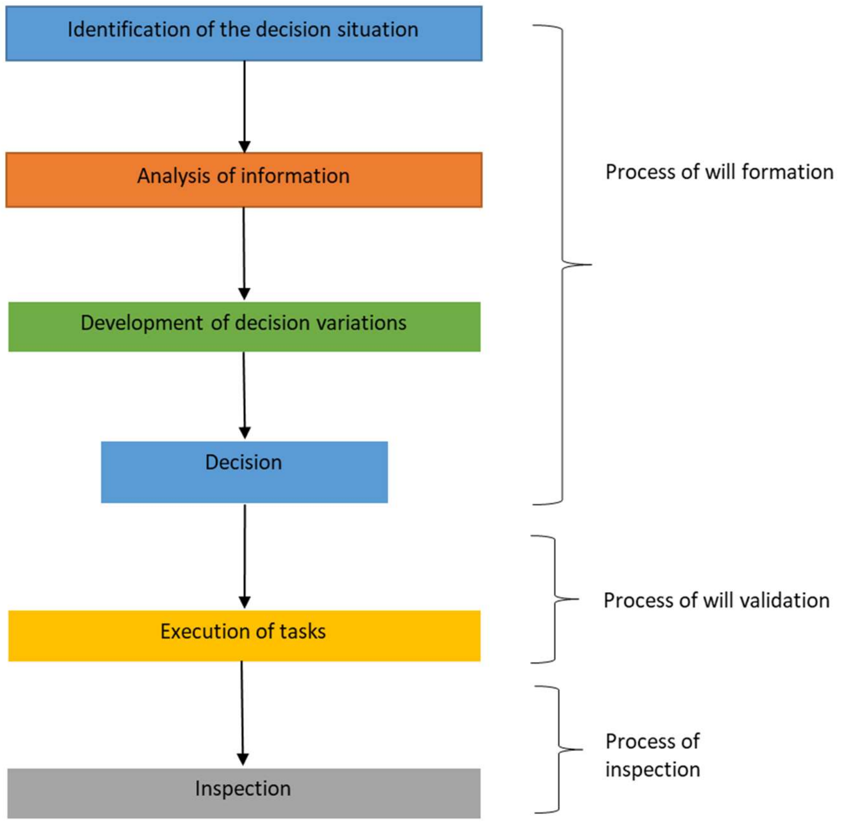

Figure 2 : Phases of management decision-making (source: [6] based on the authors' additions)

The process-system approach has highlighted the importance of the decision-maker in the process, so it is worth thinking about how much experience, how complex thinking and concentration it takes for him to make the right decision-making. [7] The person directing the remediation operation perceives the decision-making process itself, of which he is also a decisive element, in its own complexity, and is also able to recognize the dynamics of system characteristics and influence them on the basis of the extensive knowledge and experience with which he has them. The essence of the systems approach is to accurately understand how firefighting, rescue manager, with his own attitude, behavior and problem-solving ability, affects the entire system and the unit or units it controls. In applying the process-system approach, it is important that firefighting/rescue managers know the tools and solutions to support the work of those who intervene in the event of damage and to apply the optimal use of their resources in order to ensure effective and efficient damage control. [5] Based on the data of the detection, the firefighting manager, thinking in terms of the process-system approach, evaluates the solutions applicable to the given task (firefighting, technical rescue) and makes the decision according to the following diagram. If the solution used proves to be ineffective enough, it may decide to use a new solution.

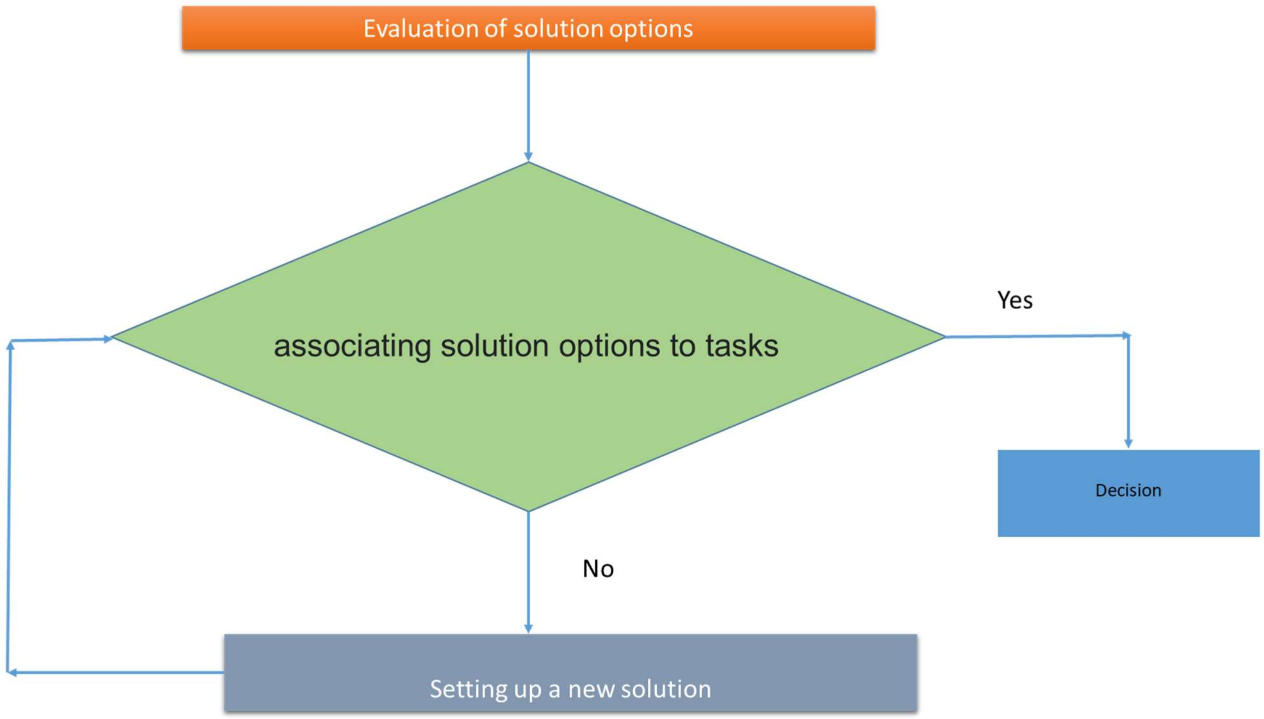

Figure 3 : Decision mechanism of the firefighting manager (Source: Authors' compilation)

From the point of view of the decision maker, the most important aspect of the process-system approach is extensive experience, a deep level of self-knowledge and a high level of awareness in the perception of a changing environment, which can be shaped by trainings and special professional trainings. [8]

Control over the implementation of decisions, evaluation of implemented, implemented decisions should be carried out in any case. Unfortunately, there is no possibility or time for direct, detailed analysis of interventions during a complex damage elimination, but after the intervention, the analysis must be carried out if possible, as we can gain valuable experience that can be used in the future. [9]

Decision support options

The work of firefighting /rescue managers can be greatly helped by the algorithms developed for each type of intervention, but due to the complexity and complexity of the given damage events, they are not always applicable. [10, 11] Various databases have already been created to support interventions in the presence of hazardous substances, which can be displayed on the spot with the help of electronic means and assist the decision-maker in his work. The decisions of firefighting/rescue managers can be greatly supported by computer programs that can help with data analysis as well as intervention planning. [12] Programs have also been developed to assist users in calculating the force-asset required for interventions and in determining alarm levels. The advantage of computer programs is that databases can be expanded, so that newly developed tools can be added, which are essential for up-to-date use. These programs are also suitable for analyzing damages that have occurred in the past, the results obtained can also be used to prepare case studies and organize exercises. [13]

Conclusions

In the course of our research, we have come to the conclusion that the requirements for the people who manage the remediation operations are constantly increasing, and the real-time decisions they make have a serious impact on the complex remediation process. The application of the process-system approach to the remediation activity greatly helps to analyze the entire decision-making process, so that adequate results can be obtained for all factors. It is also important to analyze the implementation and consequences of management decisions, because future decisions would already be greatly supported if the expected consequences of a decision could be indicated within a definable interval.

Summary

As a result of continuous technical progress, as well as changes in our world, a repercussion is occurring, and as a result, damage eliminations are becoming more complex and complicated. The effectiveness of on-site implementation is greatly influenced by the preparedness of those who manage operations. Real-time decisions made by field controllers in the firefighting/rescue manager-led unit and its surroundings can bring about decisive changes that can greatly aid or hinder the successful elimination of damage. In our opinion, one of the biggest risk factors for successful and effective damage control is the outcome of firefighting and rescue manager decisions. In our paper, we examined the process of management decision according to a process-system approach, reviewed the possibilities of decision support, and also dealt with the development of decision-making skills in order to address the challenges caused by continuous changes. With our research results, we want to contribute to increasing the effectiveness of decisions made in operation management

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ISSN 7234561-6