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Language issues, an underestimated danger in major hazard control?

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ABSTRACT

Language issues are problems with communication via speech, signs, gestures or their written equivalents. They may result from poor reading and writing skills, a mix of foreign languages and other circumstances. Language issues are not picked up as a safety risk on the shop floor by current safety management systems. These safety risks need to be identified, acknowledged, quantified and prioritised in order to allow risk reducing measures to be taken. This study investigates the nature of language issues related danger in literature, by experiment and by a survey among the Seveso II companies in the Netherlands. Based on human error frequencies, and on the contents of accident investigation reports, the risks associated with language issues were ranked. Accident investigation method causal factor categories were found not to be sufficiently representative for the type and magnitude of these risks. Readability of safety related documents used by the companies was investigated and found to be poor in many cases. Interviews among regulators and a survey among Seveso II companies were used to identify the gap between the language issue related dangers found in literature and current best practices. This study demonstrates by means of triangulation with different investigative methods that language issue related risks are indeed underestimated. A recommended coarse of action in order to arrive at appropriate measures is presented.

1. Introduction

Since 1970 UNESCO (United Nations Educational, Scientific and Cultural Organization) use the term "functional analfabetism" for those who cannot read or write enough to be self-sufficient members of society.

A global inventory of this problem is currently being compiled through a series of regional UNESCO conferences and a global conference: Confintea VI, May 2009 in Belem, Brazil. The preparatory regional conference, held in December 2008 in Budapest, Hungaria, covering the illiteracy issues in Europe and North America, linked the influx of immigrants, social inclusion, diversity and learning competencies to literacy problems and stated: "*Literacy and learning competencies are an issue throughout the region and a conceptual change seems to be needed. There is still a denial of the existence of literacy problems in several countries but new thinking on literacy places more emphasis on its importance as a core competence*." The regional report highlights the fact that millions of workers with low literacy skills form a major economic participation obstacle mainly in the more industrialised countries. In many of the countries that are part of the region, local initiatives to increase literacy exist [1]. This paper focuses on apparent literacy problems in the high risk industry in the Netherlands.

The Dutch word "analfabetisme" is in use for those who are 15 years and older and cannot read or write. In American literature the terms "low literacy", "poor literacy" and "limited English proficiency" are found. The word "illiteracy" is used much more often however. The Dutch Foundation for Reading and Writing abbreviates the UNESCO term to, simply, "illiteracy". This paper uses the term "illiteracy" as the translation of the Dutch word "laaggeletterd", identifying the adults in the Netherlands who have not reached the reading and writing skill level needed to be independent members of society. Reading and writing is a problem for 1.5 million people in the Netherlands [2]. Research has shown that truck drivers, maintenance technicians and workers in storage areas are among the professions most susceptible to illiteracy [3].

The economic situation in the European Union changed the situation on the shop floor. The number of foreign workers increases and they originate mostly from countries with illiteracy rates significantly higher than those in the Netherlands. This causes problems with verbal and written instructions, following procedures and participating in meetings.

The illiteracy aspect is dealt with by a nation wide campaign, so far leading to free language reading and writing courses for workers and to a covenant declaration between government, unions and industry with the intent to reduce illiteracy [4].

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BRZO'99 (Besluit Risico Zware Ongevallen 1999) is the Dutch implementation of the European Seveso II directive major hazard control legislation. The Seveso II directive itself mentions training of personnel at all levels in the organisation but does not explicitly address the issue of reading and writing [5].

The inability to read and write has recently been identified as a potential danger in an update of the Dutch standard for Safety Management Systems NTA-8620 (chapter 4.4.2). No measures against this type of danger are identified. This standard is mentioned here because of its exemplary lack of further content on the subject "language issues" besides the chapter 4.4.2 "trigger" remark. The standard is free and publicly available from the government. NTA-8620 is presently only available in Dutch although it is aimed at the Dutch situation with many international Seveso II companies.

In accident investigation methods causal factors related to language issues are hardly addressed. This limits the view on the true magnitude of language issues related risks [6].

Although in the Netherlands the Seveso II inspection method was updated for this, there is a need to further refine the policy set out within the regulatory government institutions to address language issues and diversity management in the near future, in line with the covenant declaration [7].

This study intends to establish both the nature and the magnitude of language issue related dangers from literature, interviews and a survey among Seveso II companies. Checks are performed using readability of company documents and evidence of occurrence of major accidents with language issues as a causal factor. The risks are prioritised and specific measures for risk control are proposed.

2. Language issues and their causes

There are many reasons for illiteracy, which have social, cultural, economic and individual – many times medical – causes. The population in the Netherlands also includes people speaking many different foreign languages and having many different cultural backgrounds. All these language issues lead to miscommunication in general and this may also happen when safety is concerned. These language problems cannot all be solved by one method at the same time [3]. Different causes and conditions require different solutions. The main causes are poor education and training and poor information exchange, in writing, verbally and even by signs or gestures. Individual factors, the multi-lingual shop floor setting and a variety of circumstances affecting communication are the conditions under which a language issue can become a safety problem. For example, people at work in a multi-lingual and multi-cultural setting need to be trained to do so. If not properly attended to, such a condition of diversity creates language barriers, unwanted non-verbal behaviour, prejudice and anxiety for the unknown [7]. Hence, along these lines, language issues can be divided in 3 × 3 classes as proposed in Table 1.

The first and second columns separate "personal development" issues from issues stemming from "foreign language" usage on the shop floor. The third column gathers all other issues, regarded as disturbing "other factors" in the working environment. For example poor education and training may result in language issues in a situation with diversity. The multi-cultural and multi-lingual "diverse" shop floor is a condition, the cause of any language issue is insufficient education and training and not diversity itself. Workers need to be trained to handle diversity. Poor written communication may lead to language issues in the presence of dyslexia. The relation between written communication problems and dyslexia is (much) stronger than between verbal communication and dyslexia. Poor verbal communication may lead to language issues in a situation with loud noise.

Further split-up into more columns does not lead to better visibility of the types of language issues identified in this study. The rows were used to allocate causes into factors groups that are both few in number and yet as independent as possible. The proposed first row, "Poor education and training" of the individual workers, is frequently mentioned in literature related to safety and appears in legislation on safe work. This centres on the individual worker's capabilities. The second row, "Poor written communication" focuses on written interaction between a reader and a writer by means of text in a document or any other written form. This looks at suitability and quality of written or displayed information transfer. Finally, the third row, "Poor verbal communication" concentrates on the imperfections in audible information exchange between people at work by means of sound and speech.

3. Language issues causing hazards

Language issues are never the direct cause: a worker must perform a language issue induced unsafe act. Therefore all accidents with '*human error*' as the direct cause are of interest.

In order to conduct a literature survey the key word '*language issue*' and both its aspects, illiteracy and foreign languages, were explored in depth.

The nature of language issues related danger was explored using a model centred around a worker about to perform an unsafe act. The worker in this model is surrounded by actors, instructions and equipment. Also the worker's own skills and knowledge are part of the model. The dangerous chemicals, accompanied by information, complete the worker model. All the actors provide input to the worker. The output is the potentially unsafe act. In major hazard control installations there are *lines of defence* (LODs) protecting against the potential *loss of containment* (LOC) [8]. The LODs must be designed to sufficiently compensate for the probability of a

Table 1
Proposed classification of language issues by cause and condition.

Cause	Condition		
	Personal development	Foreign language	Other factors
Poor education and training	Analphabetic Illiteracy Poor vocabulary Poor writing Poor reading Poor calculating	Not understood Other (local) language Used to other gestures, pictograms, symbols	Diversity
Poor written communication	Wrong language level Too large document Poor editing	Poor translation Too short display time	Medical problems (dyslexia, dyscalculia, etc.) Poor printing
Poor verbal communication	Communication via others Language skills	Multi-language shop floor Poor translator	Hurry Noise etc.

loss of containment. Around the model a wide range of interacting stakeholders was identified. Data from these stakeholders provided useful leads and background information. All this provided a series of terms suitable as input for searches in various sources. Several case studies in Seveso II companies were found showing practical effects of the national campaign against illiteracy on the shop floor. In order to handle the issue of foreign languages in the "worker" model people with a language other than the native language (in the Netherlands that would be Dutch) are placed in the category illiterate. Impact on major hazard prevention has not been assessed in these studies. Seveso II companies appear not to differ from the industry in general when it comes to illiteracy levels.

Management systems like International Standards Organisation ISO 9001, -14001 and Occupational Health And Safety Management System OHSAS 18001 hardly deal specifically with language issues but rather focus on 'communication' and 'training' issues. When it comes to "communication" management systems usually indicate what information must be transferred to a specific department, function or person. Sometimes attention is paid to readability: the documents must be typed and kept clean and tidy. The prescribed method of information transfer usually does not take into account any communication disturbances or vulnerability due to language issues such as illiteracy. This study refers to these latter issues.

A worker receiving written information while not being able to read well enough to understand it may expose two problems. Firstly, a personal development problem, the skills are not sufficient for the job at hand. Secondly, a "training" problem: the design of the training is not suitable for the worker concerned. This renders the training ineffective. A worker would generally not be likely to speak open about illiteracy problems. Companies may be unaware or ignoring them.

Schein (1996) states that safety culture, communication and language are related [9]. Methods to evaluate safety culture do not take language issues into account however [10]. The safety certification institution VCA (Veiligheids Checklist Aannemers) issues a contractors safety checklist standard. VCA have – against the economic pressures – recently introduced new requirements on the ability to speak the "shop floor language" of workers staying 3 months or longer, thus leaving the short tempory workers part of the problems unattended [11]. The literature search leads to an overview of illiteracy levels among workers in the Netherlands and – considerably higher – in home countries of foreign workers, as shown in Table 2 [12–14].

Extensive literature search also results in a listing of 22 language issue related dangers compiled in Table 3.

The dangers concern lack of coordination, knowledge and good instructions during the use of equipment and handling of dangerous substances. All directly concern the safety of the worker while dealing with the job at hand. The 22 dangers all have unambiguous links with incidents. They may each be the only cause of an incident or be one of a set of causal factors. For example "not sufficiently following procedure", danger (2), may be caused by language issues like misinterpretation due to poor reading skills, poor vocabulary or a general lack of understanding of the briefing on the job at hand. Although workers may be present on a work instruction meeting and even put their signature on the attendees list they may well have missed the main points or misunderstood part of the instructions. This way workers can be insufficiently informed about the work procedure content, danger (5). Although physically a letter or a personnel magazine containing important information arrives at a worker, poor reading skills may jeopardise the arrival of the information itself, danger (18). Other countries, other gestures: in an emergency even a head movement can be misinterpreted as a yes instead of a no or vice versa, danger (22).

The dangers are used in this study to develop a scenario based risk analysis.

Both the nature of *human error* and its magnitude were studied extensively by Reason and Williams in the eighties and nineties [15,16]. The magnitude of language issues related danger was estimated using the error producing condition frequencies. This analysis shows that language issues related human errors can mount up to 35% of all human errors. Cameron and Raman [17] show that approximately 30% of the accidents in the process industry are caused by *human error*. This leads to a rough order of magnitude estimate of some 10% of all accidents being causally related to language issues.

On this – startling – number a reality check was done with a search for evidence in major accident investigation reports. In order to do this, various sources of information such as international incident databases listed by Cameron and Raman (2005) and online data from Dutch government institutions involved in accident investigations were explored. Due to restrictions caused by cost or travel, required to get access, several sources had to be discarded from the search.

The Labour Inspectorate Department Major Hazard Control (MHC) investigates all major incidents in Seveso II companies in the Netherlands. Detailed reports, 144 in total, on incidents in the period 2002–2006 are available to the MHC department and 39 summary reports up to 2008. The 39 summary reports were searched for language issues explicitly stated as a causal factor. This qualifies 5.1% of the listed incidents. Another 12.8% on top of that show more implicitly stated language issues which are likely to have contributed as one of the causal factors. The most frequently used incident investigation method in MHC accident data is Tripod [18,19]. The detailed MHC accident reports show Tripod General Failure Types (GFTs) established as causal factors during the investigation of the incidents. Looking at the language related categories in each GFT an estimated 8.5% of the major incidents appear to be either explicitly or implicitly language issues related. Detailed and summary MHC report data are presented side by side in Fig. 1.

The Major Accident Reporting System (MARS) is used by 15 member states in the European Community to monitor major accidents as defined by the Seveso II directive. Out of more than 600 incidents listed some 246 are human error related. With the findings of Cameron and Raman [17] and the 35% language issue share in human error found in this study, this leads to an estimate of up to 14% language issues related major incidents. Since none of the 246 summary incident descriptions explicitly mention language issues as a causal factor, they must be shown as "implicitly" language issue related. This in contrast with the American Chemical Safety board (CSB) which publishes completed accident investigations on the internet. The 45 reports published there were searched for text referring to language issues as a causal factor. In total 5 reports

Table 2
Illiteracy in different countries [11–13].

Country	Illiteracy (%)	Country	Illiteracy (%)
Netherlands	10	Litowania	26
Flanders	15	Estonia	23
Germany	9	Latvia	20
Sweden	6	Former Soviet Union	24
United Kingdom	23	Former Yugoslavia	24
Ireland	25	Antilles	25
Poland	46	Morocco	72
Portugal	48	Turkey	59
Italy	32	Suriname	25
Finland	10	Afghanistan	80
Slovenia	42	Iraq	24
Hungaria	34	China	46
Romania	20	Iran	24
Bulgaria	30	Others (W)	24
Czech Republic	24	Others (NW)[a]	40–80

[a] 130 countries a.o. Cabo Verde, Egypt, Ghana, Vietnam.

Table 3
Language issue related dangers with risk ranking.

No.	Language issues related dangers	Examples of effects on the worker	Risk
1	Meeting about work not effective enough	Lack of coordination and knowledge	90
2	Procedure not followed sufficiently	Wrong actions	63
3	Written instructions/work permit not effective	Lack of knowledge, wrong actions	63
4	Verbal instruction not effective (a.o. alarm, evacuation)	Lack of knowledge, wrong actions	111
5	Not informed about work procedure content	Lack of knowledge, wrong actions	81
6	Dangers of dangerous substance not known	Not aware of danger	72
7	Safety instruction not effective (a.o. usage of safety provisions)	Unsafe actions	75
8	Communication about safety not effective enough	Unsafe actions	90
9	Procedure not sufficiently readable or not clear	Lack of knowledge, wrong actions	87
10	Change not understood (procedure, instruction, manual)	Lack of knowledge, wrong actions	75
11	Data recorded incorrectly (forms, lists)	Unreliable information	54
12	Professional keywords/jargon not known	Lack of knowledge, wrong actions	93
13	Calculation errors	Unreliable information	33
14	Mixing up left and right	Wrong place	60
15	Wrong interpretation of lists, tables, graphs and drawings	Unreliable information	81
16	Location error (map, plan view)	Wrong place	57
17	Instructions for use of equipment not effective	Unsafe actions	75
18	Written information does not ‘arrive’ (letter, personnel magazine)	Lack of knowledge, wrong actions	42
19	Safety information not understood (label, material data sheet)	Not aware of danger	81
20	Supervisor does not read well	Lack of supervision	24
21	Display information not understood	Unreliable information	93
22	Gesture, hand/arm signal not correctly understood	Wrong actions	81

were found of which 2 were discarded since they address language issues after the accident happened. This leaves 3 reports indicating some 7.1% explicitly mentioned language issues as causal factors.

The United Kingdom Government Institution Health and Safety Executive (HSE) registers major incidents at the COMAH (Control Of MAjor Hazards) office. Although the records may have an overlap with MARS data the 22 accident descriptions published there were searched on language issues as a causal factor. In total 2 reports with implicitly stated language issues were found. This suggests some 8% language issues as a causal factor.

The Dutch Government Research Institution TNO publishes a database on 22.700 accidents involving dangerous chemical substances worldwide. A search in the abstracts in their database leads to between 0.2% and 7.3% suspected to be language related accidents.

Finally, the Labour Inspectorate publishes information about 9000 industrial accidents via the internet. The accident database was searched for language related accidents. The resulting quantities found for knowledge, plans, procedures, ergonomics and communication were used to estimate language issue causal factor percentages. Two different estimates were done leading to percentages of minimum 2.0% and maximum 9.5%.

The results for the sources explored are shown in Fig. 1. The rough estimate of approximately up to 10% on basis of *human error* frequency data compares quite well to these percentages found from accident reports.

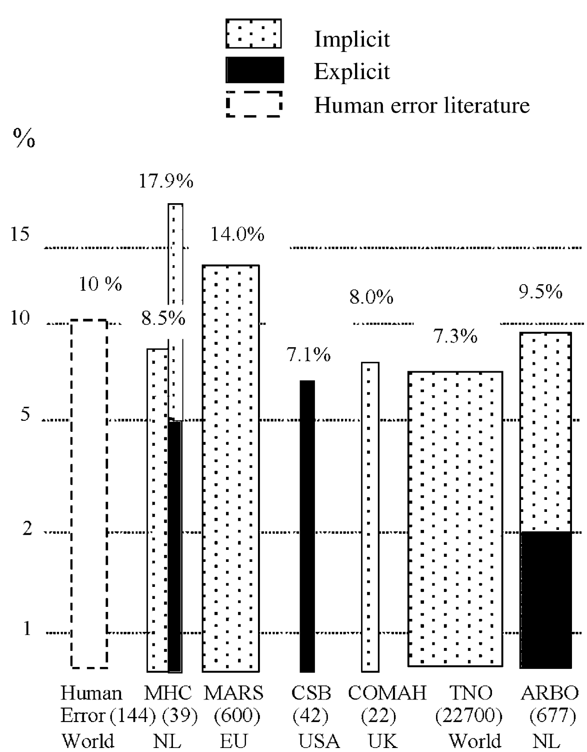

Fig. 1. Percentage of major accidents with language issues as a causal factor.

4. Language issues and accident investigation methods

Lardner and Fleming (1999) have investigated and analysed human error in the process industry. They report that 43% of human error accidents are “procedure” related [20]. Although this might be considered as indicative for the possible magnitude of language issues as a causal factor, further investigation is performed. The Institute for Safety and Crisis Management COT and the engineering and consultancy company DHV have analysed the major incident rate in the Netherlands in 2004. One of their observations was the existence of a lack of causal factors related to language issues in various accident investigation methods and they recommended further research [6].

Many accident investigation methods exist. Listings from Sklet [21] and Alphen et al. [22] were referenced to identify accident investigation methods using a classification system for causal factors. In the Netherlands Tripod [18,19], Fault Tree Analysis (FTA) [23], Management Oversight and Risk Tree MORT [24] and Systematic Accident Investigation Technique SOAT [25] have been as such methods over the last years. A causal factors listing, compiled for replacement of the Labour Inspectorate industrial accident investigation method SOAT, as introduced by Jaspers [26] was included for reference.

The lack of relevant causal factors both in accident reports and in investigation methods is one of the problems when estimating the magnitude of language related risks. Language issues are explicitly addressed in some causal factor categories but this is not so in all frequently used accident investigation methods in the Netherlands.

Therefore the categories of those methods are also searched for implicit language issues.

For each of these frequently used investigation methods their set of causal factor categories was used as a classification system covering all types of accidents. These sets of categories were then reviewed on their relation with language issues by comparing each of them with each of the 22 dangers in Table 3.

Where any of the 22 dangers can cause an event within the category an *implicit* relation with language issues was noted. Many times this led to a category associated with 10 or more of the 22 dangers. Where the category descriptive text mentioned any of the words ‘language’, ‘reading’, ‘translation’ or ‘writing’ the category was marked as having an *explicit* relation with language issues.

The distribution of explicit and implicit language issue related causal factor categories over the accident investigation methods, reviewed in this study, is presented in Fig. 2. The lack of explicitly stated language issue related causal factors in FTA and MORT methods is clear. Although explicitly stated category percentages in the other methods vary significantly the implicit language issues related categories indicate a total level between 7.8% and 12%.

The latter compares to the 7.1–17.9% magnitude found from accident report data as shown in Fig. 1. The explicit language issues related category numbers are quite different: they vary between 0% and 4%. From these estimates it becomes clear that – in general – language issues are likely to be underrepresented by a factor 4. This is confirming the lack of categories suspected by COT/DHV [6].

5. Readability of documents

Seveso II companies use several types of technical documents to communicate safety information to their staff, their guests and 3rd party workers on the premises. Although video instructions have a growing importance for visitors there is still a heavy dependence on written safety instructions. The safety rules flyer at the gate, the personnel magazine and printed work instructions are all to be read by visitors and own personnel.

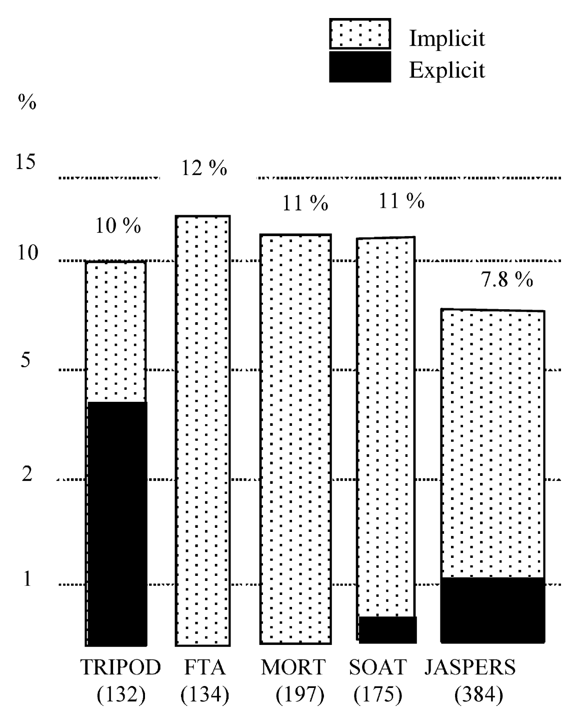

Fig. 2. Estimated percentage of causal factor categories related to language issues in different accident investigation methods.

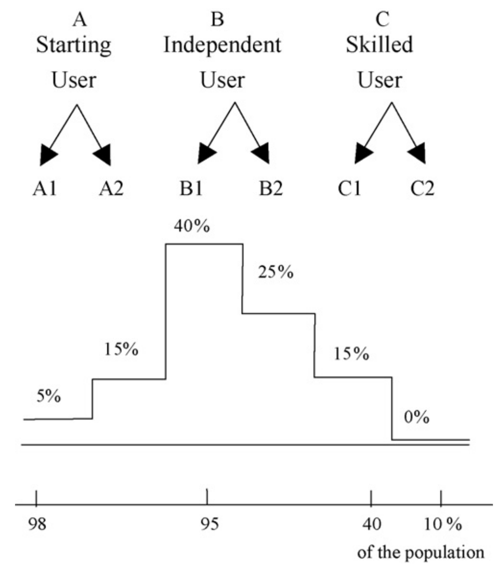

Fig. 3. Language skill levels according to CEF and frequency distribution of reading skill level among the adult population.

Tank truck drivers are identified as a separate high risk group [27]. These drivers deal with large volumes of dangerous chemicals. Therefore this study also addresses readability of the work instruction for unloading a tank truck. The Seveso II implementation in the Netherlands has led to the regulatory requirement that each member of the personnel and/or their representatives must be given the opportunity to read the company safety policy. Hence also the Dutch Major Hazard Control legislation prescribed company safety policy document was looked at. The types of documents, investigated in the experiment conducted for this study, are shown in Fig. 4 on the left hand side. They would all qualify as technical documents although also non-technical staff or visitors would normally need to read them. These documents are not intended for use by the general public. The study assumes that document readers would not differ from the general public in terms of reading skills.

Levels for expression of both language skills and document readability in equal terms were found in the Common European Framework of Reference (CEF). The CEF framework is depicted in Fig. 3.

For this study it is used to describe reading skills, being part of language skills. CEF is built on three basic language user skill levels:

(A) The starting user of a language, able to discuss personal daily matters in the direct personal environment only, and hence not able to fully participate in society and in a work environment.
(B) The independent user, able to take care of things as they are in normal life, including some writing and travelling, and able to express well during conversation.
(C) The skilled user, able to read, write and understand large and complex documents and able to use the language fluently and concise in any social or professional situation.

Each of the basic levels is split into two sub-levels 1 and 2 leading to the 6 level scale A1. . .C2 for language skills as shown in Fig. 3.

The frequency distribution of CEF level reading skills among the population was investigated by Driessen et al. [28]. This distribution leads to a cumulative percentage scale of reading ability for the population. Both distribution and cumulative scale are shown at the bottom of Fig. 3.

The definition of “illiteracy”, presently used in the Netherlands, lines up with levels A1 and part of A2 in CEF. About 10.3% of the Dutch working population is in A1. Some 27.1% is in A1 and A2 together. In total about 13% of the total adult population qualifies for the current definition of illiteracy, 1.5 million people.

The United Nations Organisation for Economic Cooperation and Development (UN-OECD) reported an international study in 2000, referred to as the 1994 International Adult Literacy Survey (IALS), that uses a 5 skill levels system [13]. At least 24.5% of the adult population does not reach the IALS-3 "qualification" level required to participate in the "information society" the Netherlands are heading for in the near future [29]. Apparently between 24.5% and 27.1% would not qualify for IALS-3. The IALS-1 level corresponds to the combination of the A1 and A2 levels in the CEF system. Up to 20% of the Dutch adult population would qualify for IALS-1 but that is including 1.7–2% "analfabetisme". An update is currently being carried out, the Adult Literacy and Life skills (ALL) project. Results for the ALL study in the Netherlands have not been published yet.

Looking at other countries there is a variety of local definitions. Therefore the IALS-1 population percentages for adult document literacy level were used where available in Table 2. For France the ANCLI/INSEE (2005) figures for "illetrees" were used [30]. The European Parliament document dated June 25, 2001 lists (functional) illiteracy percentages for the adult population of new EG countries [14]. Also several figures were used as published by the Dutch Language Research Institute "Nederlandse Taalunie", originating from a.o. UNESCO and World bank data [12,31].

A higher reading skill level allows an individual to read a more complex document. A more complex document is less readable. This study uses the CEF scale also for readability. Different specialised consulting companies offer linguistic advice on how to improve readability of a document on a business to business commercial basis. This advice is not found to be used by Seveso II companies during interviews and survey.

Many different indicators have been developed over the years to (automatically) evaluate the readability of a text. In this study some 20 of them were identified in a literature survey. The indicators all require analysis of a sample of the text in the document to be assessed. A formula, using variables such as the length of a sentence, the number of syllables and the length of a word, calculates a numerical indicator value. This indicator approach does not cover all of the readability to be assessed however. There are also the size, symbols, structure, typography, white space, illustrations, use of colour and, summarizing them all, the lay-out to consider.

No empirically validated document readability test method exists that integrates both the text and the graphical lay-out component of a document was found in the literature however.

Many stakeholders provide lists of recommended lay-out features in a document to "improve" readability. CINOP is an independent, (inter)national research and consulting institute on education and development and acts as National Agency for the European Commission-programme Life Long Learning. An elaborate list of 9 readability requirements was developed by CINOP in 2007. In this list 5 requirements deal with the text complexity and 4 with its appearance. The improvement of readability by using a good lay-out was implied to be limited to a maximum of one CEF level.

This means that although the readability text indicator approach is not the only aspect it remains the most important aspect in the assessment of document readability. An added component in document readability reflecting the lay-out remains therefore relatively less important. This opens up the possibility of a single integrated readability scale for the evaluation of both text and lay-out components. With two proprietary series of Dutch "calibration documents" available, a choice of some 20 text indicator formulas found in literature and a high commonality in the commercially suggested lay-out features to be used in a document this turns out to be conceivable. Therefore a simple readability assessment scale, including both the text and the lay-out of the document, expressed in a single readability value, the *effective* CEF level, was developed in this study.

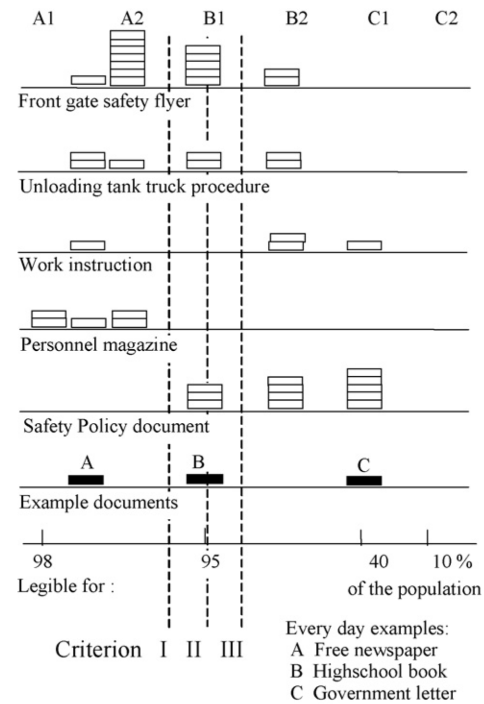

Fig. 4. Readability of 43 Seveso II company safety related documents compared to every day examples.

A suitable existing numerical text component readability indicator was selected first. The 20 indicator formula values were calculated for two series of Dutch language calibration documents available from two different proprietary sources. The calibration texts, 15 in total, were ranked on complexity along the arithmetic mean of the 20 indicator values. The indicator formula reflecting this ranked complexity sequence closest was selected as the best. This formula is the Flesch Reading Ease Score (FRES) [32]. Its numerical values typically range from 0, very complex, to 100, easily readable. A match between numerical indicator values and the CEF reading skill levels between A1 and C2 was obtained this way. One CEF level corresponds to 20 FRES points. These numerical values provide the basis for the document readability scale.

Next the lay-out component was quantified. The 4 appearance related CINOP readability requirements were converted into a list of 9 separate attributes. The number of pages in the document was used as the 10th attribute. In this way a 10 steps 'easy to spot' attribute check scale was obtained. By adding up the check points a numerical value is found. This value, maximized to 20, i.e. corresponding to maximum 1 CEF level, is used on top of the FRES value to indicate the assessed improvement of readability by lay-out attributes found.

Finally the *effective* CEF level is found from the sum of these two numerical values found for a document via a conversion table. This tool was then validated by a reality check on 'every day' example documents like a free newspaper, a magazine, and a complicated government letter. Although a comprehensive empirical test could further substantiate the validity of the tool in the future, the *effective* CEF level scale was used to assess readability of 43 Seveso II company documents. The result is shown in Fig. 4.

A simple criterion to evaluate whether readability of a document is sufficient was defined by BureauTaal in a study on behalf of the Ministry of Social affairs and Employment. BureauTaal is a privately owned company and established linguistic advisor of a.o. Government institutions, companies, health care and education.

When someone's own skill resides on level A2 it is – with considerable difficulty – possible to read a document written 1 level higher, so a readability level B1. The criterion for good readability was set on the B1 level since 95% of the general population in the Netherlands can (just) read this [33]. This study underlines that, besides the fact that this leaves 5% unable to read a B1 level document, some 15% of the Dutch adult population has considerable difficulty in reading such a document. This can only be considered as an avoidable risk when safety related documents are concerned.

The practical difficulty here is the choice of a suitable readability criterion. This study considers 3 different criteria. Each of them leads to a different percentage of safety related technical documents that is not sufficiently readable for most of the adult population. The notion that the documents are "safety related" is important because there is a link to unwanted accidents. The users of the documents are own personnel, third party personnel, suppliers, (truck)drivers and visitors on site of a Seveso II company. This group is not the same as the general public but there is no obvious under- or over-representation of illiteracy among them. The frequency distribution of the Dutch adult population CEF level reading skills is therefore used for this study. Since the document readability assessment scale, as developed and used in this study, is insensitive to "jargon" or job/profession-specific words, the results found are valid for both technical and non-technical readers.

The three criteria are also shown as vertical lines in Fig. 4. Documents placed at the left hand side of the line are sufficiently readable, when placed on the right hand side they are insufficiently readable. The 3 criteria are:

I A2 criterion	95% can (easily) read it
II BureauTaal B1 criterion	95% can (just) read it
III Statistical criterion	85% can (just) read it

I: 95% can (easily) read it

In total 17 documents (A1–A2 levels) have a good readability for 95% of the population. These 17 out of 43 documents in this study are suitable for exchange of safety information, the remaining 26 documents, so 60%, are unsuitable for written safety information exchange.

II: 95% can (just) read it

Using the BureauTaal 95% criterion some 27 documents would be appraised as (just) readable for 95% of the population. So, this criterion indicates that 37% of the documents (B2 level and higher) is not sufficiently readable.

In fact 10 documents (B1 level) are just readable with considerable difficulty. This renders any responsible use of the 95% BureauTaal B1 criterion for safety related documents virtually impossible. This infers that B1 and higher text complexity levels are unsuitable for safety related documents. Use of the BureauTaal B1 criterion is therefore unsafe.

III: 85% can (just) read it

By combining the frequency distributions of reading skill level of the Dutch population and readability levels of the 43 documents a third criterion is found. It can be deduced what percentage of the potential readers would actually be capable of understanding the information that the document is supposed to convey. In this case statistically 86% can just read the documents. For this sample of 43 documents 14% of the readers would be incapable of understanding the documents, 18% would have considerable problems in grasping the document contents and the remaining 68% of the readers would have no difficulties reading the documents. Hence in total 32% of the investigated documents are not sufficiently understandable. The statistical criterion is therefore even more unsafe.

These three criteria for readability, applied to this sample of 43 safety related documents, indicate that Seveso II companies write between 32% and 60% of their safety related documents in a too high CEF level.

This demonstrates that roughly 50% of the safety related documents in Seveso II companies are unsuitable for written safety information exchange.

6. Language issue related risks

The risk associated with a danger is the result of both the probability and the effect of a sequence of events, caused by the danger, leading to an incident. This probabilistic way of looking at risks is chosen for analysis of the language issue related dangers. A deterministic approach was found to be not practicable. These sequences of events, referred to as scenarios, were developed on basis of the 22 language issues related dangers found in literature during this study, on the error producing circumstances identified by Reason [16] and on accident report data. Their respective risk was quantified by using the literature data on '*human error*' frequencies and a count of major accidents reports mentioning language related causal factors performed in this study. Effects of accidents were noted from available accident data or else assumed to be in line with other major hazard incidents. Plotting the developed scenarios in a risk matrix, thus mapping them in a field of probability versus effect, allows appraisal of their relative importance. This risk matrix was used to rank the language issue related risks top-10 in decreasing order of importance:

Very high risk
1. Misunderstanding
2. Deviation from instructions
3. Situation unknown
4. Activity not done
5. Design not understood
6. Habit intrusion

ALARA (As Low As Reasonably Achievable) risk
7. Danger underestimated
8. Not used to situation
9. Insufficient education level
10. Violation of rules

The risk order reflects back on the relative importance of the 22 dangers found in literature. For a danger that can cause, or propagate, a specific scenario a numerical value was used representing the location of the corresponding scenario in the risk matrix. A danger may be related to more than one scenario and vice versa. The relative risks associated to all dangers coming from all scenarios were then found by adding up these numerical values. This was used to establish a ranking order list for the 22 dangers (see Table 3 right column).

The original 'worker model' used for literature search showed 3 different types of instructions and two types of equipment. During this study this split-up was found to have no practical use. The model was therefore simplified to show knowledge and skills, instructions, coordination, equipment and dangerous chemicals as the five decisive inputs a worker gets at work. The worker model was further elaborated by adding the 22 dangers, as listed in Table 3, with their relative importance, adding up per group as shown in Fig. 5. All this clearly identifies the importance of instructions as the single biggest source of language issues related dangers of the five input groups.

Because of these five input groups the worker model can be graphically depicted as a hand. The output is an action by the worker with a probability P of being unsafe. A rough estimate of P was performed on basis of *human error* literature. Reason (1997) states that for the generic activity "*E - Routine, highly practiced, rapid task involving relatively low level of skill*" the probability of a skilled worker performing an unsafe act during normal routine operations appears to be as high as 0.02, irrespective of any HEART factor to be applied [15,16]. This generic activity would match with the activities per-

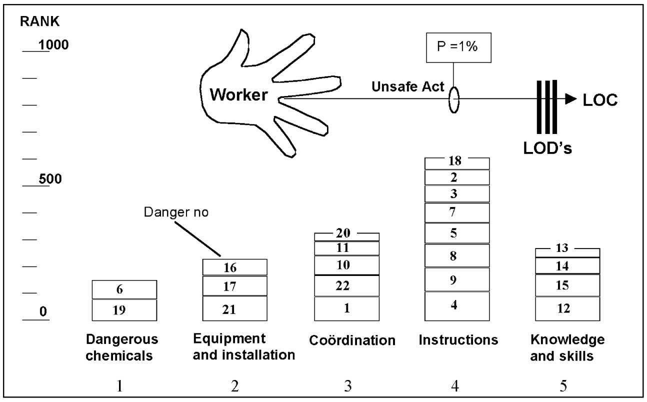

Fig. 5. Model around a worker showing 22 language issue related dangers in five groups and their risk ranking as listed in Table 3.

formed by for example drivers, maintenance engineers and storage employees in Seveso II companies. Since in this study a maximum of 35% was found for the language issue related part in human error the probability becomes maximum 0.7%. This must be regarded as a rough order of magnitude estimate since no HEART factors were applied nor is there any specific experimental evidence based on language related human errors found in literature. Therefore in this study a rounded value of $P = 1\%$ was used.

7. Dealing with language issues in practice

The language issues related scenarios listed above require different measures to be taken. Scenarios 1, 2, 4 and 10 implicate supervisory solutions. The scenarios 2, 3, 4, 5 and 7 need readability improvement and finding alternative ways to inform workers of procedure, installation design, dangers and safety precautions. Scenarios 6, 8 and 9 require attention of the personnel department. If hired, people need sufficient training so the recruitment process needs to ensure that workers are sufficiently capable of being trained.

In the Netherlands the Seveso II directive applies to some 800 installations owned by some 600 companies.

Current best practices in Seveso II companies were investigated with interviews and a survey.

Based on the findings from literature research, orientation interviews held among inspectors of the regulatory institutions involved and verification interviews held at several companies a questionnaire on handling of language issues was developed.

The orientation interviews were conducted as e-mail conversation or as an open 1 to 1 conversation about the question whether there is a relation between language issues and safety. In total 16 labour inspection major Hazard Control specialists, 3 fire brigade specialists, 2 police officers and 2 safety scientists have participated. Several environmental control officers were also contacted. Except the latter, all regulatory institutions recognise the relation between safety and language issues and confirm this with examples and mention problems in their field of work.

The main findings from the orientation interviews are:

- Standards for legally required Risk Assessments in companies do not deal with language issues related danger.
- Regulatory institutions have no inspection tools in place for appraisal of language issue related risk control.
- Inspection on safety policy is affected by poor language skills among site managers in some cases.
- Many examples of accidents with language issues as a causal factor are recorded.

The verification interviews, intended to test the survey questionnaire, were conducted with a conversation protocol addressing the subjects in the questionnaire concept design. No evidently missing subjects were found so the questionnaire was finalised and distributed among 200 Seveso II companies. The survey was handled by the ministry of Social Affairs on behalf of the Technical University of Delft and the Labour Inspectorate. All companies were stated to be at liberty to respond in the cover letter. The survey questionnaire was answered by 64 Seveso II companies during the months December 2008 and January 2009.

The main result is that on the one hand 76% of the companies acknowledge language issues as a danger but on the other that 65% of the companies have no risk controls in place whatsoever.

In total 16 best practices were found to be in use. Only 5 of these best practices are used by 50% or more of the companies. Table 4 lists the best practices found and their usage in Seveso II companies.

A gap analysis was then performed to identify the areas in most need of improvement.

The main issues found are:

(1) 82% of the companies are not informed about language issues by their industry association advisors.
(2) 65% do not mention language issues anywhere in their management systems.
(3) 36% do not appoint a contact person/translator for a group of foreign workers.
(4) 33% do not regard language issues as one of the causal factor for major accidents.
(5) 32% ignore illiteracy among foreign workers in their own language while providing translated documents.
(6) 29% attempt to improve readability of safety related documents by using better lay-out only.
(7) 17% issue safety instructions to foreign workers in writing only.
(8) 14% do not verify whether safety instructions are understood before work commences.
(9) 11% acknowledge illiteracy among own personnel but do not act on this.

7.1. Recommended coarse of action

- The proposed '3×3' classification of language issues needs to be further explored and developed. Once established as a management tool it will provide a structure fitting around all language issues.
- The readability assessment of documents using the '*effective* CEF level' is simple to use by any author writing any document. Validation of the *effective* CEF level scale needs to be strengthened by empirical testing.

Table 4
Language issues: best practices in Seveso II companies in the Netherlands.

76% acknowledge the link between language issues and safety
73% consider language skills of own employees
54% do more on 3rd party worker safety than written instructions only
51% require language skills of 3rd party workers
50% write clear documents using both readability level and lay-out
46% check individually whether safety instructions are understood
32% have instructions in various languages available
30% acknowledge miscommunication as an important language related danger
21% recognise that not following of procedures can be a language related danger
19% appoint a contact person for a team of foreign workers
17% consider language issues in their safety management system
14% conduct training in workers own language
10% require worker verbal skills in Dutch, German, English or French
6% use Dutch language courses
5% recognise language issues as a causal factor for incidents
3% use (more) pictograms

- The 'worker model', showing the language related dangers in five groups, can be further developed into a practical tool for language issues related risk reduction.
- The design of a 'readability KPI' (Key Performance Indicator) to monitor readability of safety related documents is investigated and found to be feasible in this study. A pilot project is suggested to validate it.
- Further detail in the 'risk ranking' analysis can be obtained by use of commercial information sources. This will enable branch organisations and companies to carry out their own specific risk assessments.

8. Conclusions

Companies are progressively developing ways to deal with language issues. Creative and inspiring new ideas find their way to the shop floor. Not all of these ideas are based on safe and solid ground however. For example, an increasing number of companies now face 10 or more different languages on their shop floor. Many companies choose to translate their instructions in a series of different languages. This ignores the fact that many workers from abroad are not able to read – well intended – documents in their own language due to illiteracy. Companies put considerable efforts in document lay-out expecting that to solve all readability problems. Another example is putting simple bits of text in complicated procedural texts. There have been experiments to use simplified language in instructions. If not properly done, in this case inconsistency in the use of simple text by mixing it with normal language, this was reported to even increase the errors [34].

The results from the survey indicate that companies often ignore the dangers and the risks associated with language issues. The contrast between that and the widely accepted and confirmed relation between language issues and safety could not be bigger. The illiterate indigenous or foreign worker, put in the middle of all this is the potential victim, not the cause. Their continued contribution to the Dutch economy is much needed in the increasingly competitive global market. This reminds of the historical mistake made in Marcinelle, Belgium on August 8, 1956. Then a language issues related mining disaster killed 262, mainly Italian, workers. As a result the much needed Italian workforce turned away from Belgium all together [35].

Underestimation of language issue related dangers is now becoming apparent and is confirmed by method triangulation. Underestimation was found in four independent ways:

- Accident investigation methods allocate a factor 4 to few causal factors for language related incidents.
- 76% of the Seveso II companies acknowledge language issue related risks while 65% do not control them.
- Between 32% and 60% of safety related documents is not sufficiently readable.
- Illiteracy now considered to be 10% of the adult working population needs to be redefined to 25% not reaching the IALS-3 start qualification level, required to participate in the "information society" in the near future.

So, in conclusion, language issues are indeed an underestimated danger. Illiteracy among the workers is not identified as a safety risk in major hazard companies. With the continuing influx of thousands of workers from many different countries this needs urgent attention of both the companies and the regulatory institutions.

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