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Using the ALARP principle for safety management in the energy production sector of chemical industry ☆

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A B S T R A C T

In the context of chemical industry, in particular in high hazard industries, the adoption of safety measures is essential to reduce risks and environmental impacts, due to the release of dangerous substances, at level that is reasonably practicable. The ALARP (As Low As Reasonably Practicable) principle is broadly used for decision-making in safety management, supported by cost-benefit analyses and the grossly disproportionate criterion, but without paying the proper attention to the decision frame (defined by the level of uncertainty and knowledge of the chemical phenomena, the use of best available technologies, the potential of major losses due to the release of hazardous materials and other items). In this paper, by examining the energy production sector of chemical industry, it will be argued that the decision context makes the application of the ALARP principle not always proper, whereas a dynamic interpretation, in which decisions are made oscillating between two borderlines, where in one case reference is made to expected values and in the other one to the precautionary principle, is more appropriate.

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1. Introduction

Chemical industries, in particular those subject to the Seveso Directive (so-called high hazard industries), pose several safety concerns that are due to potential releases of hazardous materials in the environment and their following escalation in fires, explosions and toxic dispersions. The adoption of safety measures for a company is essential in order to reduce risks and environmental impacts. Several risk management principles are available to guide the decision-making in safety management [19], amongst them one is the ALARP principle. According to this principle, risks and environmental impacts should be reduced at a level that is "as low as reasonably practicable", which means that measures for the prevention of equipment failures and losses of containment and for the mitigation of the consequences of potential accidental scenarios have been implemented, provided that it cannot be demonstrated that the costs are grossly disproportionate to the benefits obtained; ref. e.g. [27], IRGC [30], Bedford and Cooke [17], Bahr [16] and Vinnem et al. [37].

The CCPS [21] guidelines for the Chemical Process Quantitative Risk Analysis, commonly used in the context of industries at major risk refer to the use of the ALARP approach. Their application is firstly based on distinguishing between an intolerable risk level, which must not be exceeded, and a negligible risk level which does not raise either individual or public concern. Between these two limits (the so-called

tolerability region), the application of measures for risk reduction are prescribed, with respect to the ALARP principle. Such limits are fixed in the United Kingdom and the Netherlands, with the Dutch limits being more restrictive than their British counterparts, which are commonly used in risk management in many other European countries. Moreover, the CCPS guidelines assert that the 'gross disproportion' test, required for ALARP in the UK, allows authorities to demand the achievement of risk levels much lower than the specified risk criteria and that in most industries the actual risk levels achieved are at least an order of magnitude below the risk criteria. In contrast, in the Netherlands, the process for balancing the costs of risk reduction against the derived benefits does not require a gross disproportion. The Petroleum Safety Authority Norway [35] sets requirements for oil and gas companies operating on the Norwegian continental shelf (NCS), stating that: "In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved". Although the acronym ALARP is not specifically mentioned here, a 'disproportionate' criterion is specified to guide decision-making.

From a chemical company perspective, there is a burden of proof on the company in applying the ALARP principle [29]. A safety measure is to be implemented unless the manager can demonstrate an investment cost that is assessed to be unreasonable when compared with the as-

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sumed benefits in reduced risks due to releases of hazardous substances. In that sense, the ALARP principle gives strong weight to the cautionary principle, which is a basic principle in risk management, expressing that in the face of uncertainty, caution should be a ruling principle, for example by not starting an activity, or by implementing measures to reduce risks and uncertainties [15,27].

In contrast to the ALARP principle, decisions can be made with reference to expected values, as discussed in Ale et al. [7] and Ale [6]. Little or no weight is then given to the cautionary principle. The arguments for using expected values as a basis for decision-making under uncertainties is from the portfolio theory [33]. This theory is based on the statement that the expected value of the portfolio plus the systematic risk (uncertainties), caused by events affecting the whole market, is the value of a portfolio of projects and that the unsystematic risk (specific project uncertainties) can be ignored in case of a large number of project.

Based on the above argument, we discuss the implications of using the ALARP principle in safety management of chemical industry. Two cases are investigated, one relates to an inefficient use of resources, the other one concerns when scarce resources are available for safety. Even if the attention is focused on chemical industry our discussion is to a large extent general and could also be applied to other industries.

We show that the ALARP principle is considered an appropriate principle in safety management only if the grossly disproportionate criterion is interpreted differently for different decision-making contexts, such that the principle ranges from one extreme, where decisions are made with reference to an expected value, to another, in which the cautionary principle is adopted without any reference to cost-benefit (cost-effectiveness) analyses. A static decision-making principle, where the balance between the expected values and the safety concerns is fixed, cannot be appropriate as a ruling principle in safety management, as different decision-making contexts require different decision-making principles.

The paper is organised as follows. Section 2 focuses on how to implement ALARP and the grossly disproportionate criterion. Section 3 discusses how much weight should be given to the uncertainties in safety management. In Section 4, we examine the appropriateness of using ALARP as a ruling principle in safety management. Then in Section 5, by means of some case studies, collected from the energy production sector, we provide a discussion and comments about the application of the ALARP principle in chemical industry and its dynamic interpretation. Finally, in Section 6, we draw some conclusions.

2. Implementation of ALARP and the grossly disproportionate criterion

The ALARP principle is adopted by several industries, such as, for example, the oil & gas and nuclear industries (see e.g. [31,36]) and chemical industry i.e. oil refining, energy production, conversion of raw materials, etc. (see e.g. [18,23,26]).

In verification of ALARP and the grossly disproportionate criterion, different tools are used, such as cost-benefit analysis and cost-effectiveness analysis (see e.g. [32]). The role of such analyses in ALARP processes was discussed, e.g. Aven and Abrahamsen [13], where it was concluded that cost-benefit (cost-effectiveness) analyses should be used with care, as they do not give sufficient weight to the uncertainties, since the methods applied are based on an attitude to risks and uncertainties which is risk neutral and thus in conflict with the use of the cautionary principle and ALARP.

To better take the uncertainties into consideration, Aven and Vinnem [15] suggested an alternative approach, which was further developed by Aven [10]. This approach, which we refer to in the following as the layered approach, consists of three steps as shown in Fig. 1.

In the first step, a crude analysis is carried out. According to the approach, the safety measure should be implemented in situations with low costs. Otherwise, one needs to carry out more detailed analyses before a decision is made. From the second step of the approach, a
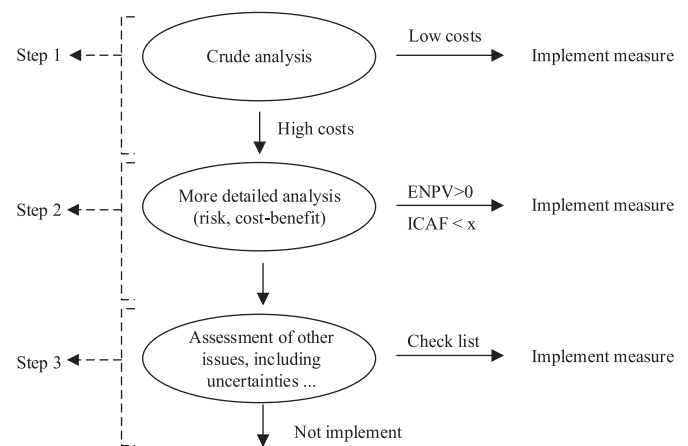

Fig. 1. Layered approach for implementing ALARP and the gross disproportionate criterion [10].

safety measure should be implemented according to the ALARP principle if such an investment is appropriate from a cost-benefit (cost-effectiveness) analysis point of view. This is intuitively appealing. One can, for example, conclude that the costs are not grossly disproportionate to the benefits obtained if the expected benefit is higher than the expected costs. One may also decide to implement a safety measure according to the layered approach, even if the cost-benefit (cost-effectiveness) analysis concludes upon no investments, which is shown in the third step of the approach. High levels of uncertainty, among many other issues can justify investments in a safety measure. Examples of issues other than uncertainties that need to be taken into consideration are: Does the measure significantly increase the manageability? Does the measure contribute to obtaining a more robust solution? Is the measure based on best available technology (BAT)? Are there unsolved problem areas: personnel safety-related and/or work environment-related? Are there possible areas where there is conflict between these two aspects? Is there a need for strategic considerations? For a full review of the layered approach, we refer to Aven [10]. See also NORSOK Z-013 [34].

3. Different perspectives on how much weight should be given to the cautionary principle

One main challenge in decision-making under uncertainty is to decide how much weight could be given to the cautionary principle. Three different perspectives could be applied as described in Abrahamsen and Abrahamsen [2] and Sørskår and Abrahamsen (2016).

One perspective is to use a traditional cost-benefit (cost-effectiveness) analysis. The decisions are then made with reference to expected values, which means that limited or no weight is given to the uncertainties and the cautionary principle; see also Fig. 2. We refer to this way of interpreting the ALARP principle as the 'extreme economic perspective'.

The argument for focusing on expected values is related to the portfolio theory, which states that the average of a number of random quantities can be accurately approximated by the expected value when the number of quantities is high.

The use of expected values as a basis for decision-making under uncertainty has been thoroughly discussed in the literature; see for example Abrahamsen et al. [5], Ale et al. [7], Aven [11] and Aven and Renn [14]. It is argued that expected values should be used with care, as the uncertainties are not fully addressed. More weight should be placed on the cautionary principle than what is made through expected values. The problem is that, if one has the potential for large losses, the use of expected values could be misleading. With many activities/projects (having a societal perspective), the expectation could be more informative, more like the average value, but the prediction can still