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Challenges and new trends

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Security risk assessment and management in chemical plants: challenges and new trends

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Abstract

The present study is to point out the outcomes of the Seminar on the Chemical Weapon Convention (CWC) and Chemical Safety and Security Management for Member States in the Asia Region held by Organization for the Prohibition of Chemical Weapons (OPCW) in Doha, Qatar, in February 2017. The seminar was aimed at supporting chemical safety and security management in the chemical industry in Asian countries. Overall goal was to sensitize States Parties to the new approaches that can be adopted in relation to chemical safety and security management, with a particular focus on providing assistance to small and medium-sized enterprises. This article reflects the observations made by keynote speakers via their interaction with participants from Asian State Parties during presentations' questions & answers sessions and following workshops. The article is an attempt to highlight the challenges in security risk assessment and management of chemical facilities and discuss some new trends for further improvements.

Keywords: Security vulnerability assessment; Chemical plants; Mutually interactive parameters; Bayesian network.

1. Introduction

Large inventories of hazardous chemicals which can cause catastrophic consequences if released maliciously, the presence of chemical agents which can be stolen and be used either in later terrorist attacks or in making chemical and biochemical weapons, along with the key role of chemical plants in the economy and the public welfare and as an integral element in the supply chain have made the security of chemical plants a great concern especially since 9/11 terrorist attacks in the US. Aside from the importance of chemical plants themselves as potentially attractive targets to terrorist attacks, the usage of chemicals in more than half of the terrorist attacks worldwide (Figure 1) further emphasizes the security assessment and management of chemical plants.

Figure 1. Type of terrorist attacks worldwide in 2015 [1]

Although the terrorist attacks to chemical facilities (excluding the ones located in war zones) have been few and far between, the risk of terrorist attacks should not be underestimated by authorities and plants' owners and security management. Recent attacks to two chemical facilities in France in June and July 2015 [2,3] raised a red flag about the imminent risk of terrorist attacks to chemical plants in the Western world.

Aside from the regulations, standards, and guidelines set forth by, among others, the Centre of Chemical Process Safety (CCPS) in 2003 [4], American Petroleum Institute (API) in 2003 [5], and The Chemical Facility Anti-Terrorism Standards (CFATS) in 2007 [6] to fulfill the Homeland Security Appropriation Act of 2007, still many chemical facilities in the U.S. containing Chemicals of Interest (COI) as denoted in the Appendix A of CFATS are not willing to submit a Top Screen consequence assessment to the Department of Homeland Security (DHS). Not to mention that the lack of relevant regulations and unwillingness of the chemical and process industries in European countries and in the developing countries to establish and implement security risk assessment and management is much more severe.

Besides a lack of efficient regulations, factors such as loose supervision of law enforcement (if any), handling security by means of the same approaches and experts of safety, lack of communication and sharing of information and knowledge, application of primitive and outdated risk assessment techniques and insufficient knowledge of state-of-the-art quantitative risk assessment (QRA) methodologies are among those which add insult to injury, accounting for the lack of or inefficiency of security risk assessment and management of chemical plants not only in developing but also developed countries. In the following, a number of challenges and new trends will be discussed in more detail.

2. Challenges and new trends

2.1. Hierarchical approach to security risk assessment

As previously mentioned, CCPS [4] and API [5] were among the first to issue guidelines for security (vulnerability) risk assessment of chemical and petrochemical facilities. However, their methodologies suffer from linearity and being incapable of considering mutual interactions among security risk parameters. For example, consider the linear methodology developed by API [5] as depicted in Figure 2(a), where the security parameters are hierarchically scoring in a top-down fashion starting from asset identification and consequence analysis in the first step, threat assessment and attractiveness analysis in the second step, the vulnerability assessment in the third step, and so on. As a result of such linear approach to security risk assessment, for one thing, the impact of a plant's vulnerability cannot fully be taken into account in assessing the attractiveness of the plant since the former is performed after the latter (see Figure 2(a)). Nevertheless, as can be seen in Figure 2(b), the vulnerability should play a role in attractiveness analysis as the more vulnerable a chemical plant the more attractive it could be to the eyes of even less-equipped terrorists. It is worth noting that attractiveness and vulnerability have some basic factors in common. When such basic factors are considered for attractiveness assessment, even the liner assessment could to some extent include the impact of vulnerability on attractiveness

Figure 2. (a) API methodology [5] for security risk assessment. (b) The interaction among the security risk parameters.

The overlook of the mutual interactions of this kind can undermine the reliability and validity of the security risk assessment. Inspired by CCPS [4] and API [5] methodologies and irrespective of the adopted technique for security assessment – whether attack tree or Bayesian network – most of the developed methodologies since 2003 can be criticized of the same hierarchical approach to security risk assessment. To address this issue, the applicability of techniques such as analytic network process (a multi-criteria decision making technique) [7] and Petri nets [8] which facilitates the feedback (mutual interaction), loops, and non-linear analysis can be examined.

2.2. The role of education and ethics

Education on chemical safety and security (CSS) with "chemical ethics" as groundwork is a possible instructional method that may prove essential to the successful implementation of security risk mitigation measures, and improve security risk management in chemical plants. This can be a semester-long formal education for professional chemists or engineers in a classroom setting such as the course recently offered in the Institute of Chemistry, University of the Philippines-Diliman (see Appendix for more details) or simply an in-house training for workers administered inside a chemical facility. This type of approach in educational activities will play a significant role in enhancing the prevailing chemical safety and security culture of a facility, and contribute to the vetting process normally done by companies in hiring their employees.

Instilling a "chemical conscience" to chemical professionals will not only mitigate insider-involvement security breaches, but also help ensure that these workers will do their jobs to the best of their abilities, keeping in mind the effect of their practice to the company, their community, and the environment. This will make ethics in the practice of chemistry a vital component in the design and administration of educational and awareness activities pertaining to chemical safety and security.

Also, the sequence of topics at which chemical safety and security is taught can be beneficial to the learning process. Chemical safety concepts, which encompasses knowledge on chemical reactivity, chemical value, appropriate chemical storage, and chemical transport is best taught prior to security concepts, as this will dictate on how security measures in a chemical plant are designed [8]. A simple example is the need for knowledge on chemical reactivity to determine whether a chemical is attractive to adversaries before appropriate access controls can be chosen, or decide on where to store the chemical in a graded protection system of security control. Chemical safety therefore walks hand-in-hand with, but perhaps a step ahead of security, in ensuring the overall hygiene of specific risk management measures employed in a chemical plant. Perhaps, the same sequence of concepts should be applied when it comes to teaching CSS.

2.3. Security consequence assessment vs. safety consequence assessment

Considering a security risk assessment in form of a Bow-tie diagram, where the occurrence of a successful attack is in the centre with the causes and countermeasures on the left hand side (upstream) and mitigating barriers and the consequences on the right hand side (downstream), a majority of previous work in the field of security risk assessment has been devoted to the upstream. In this regard, the majority of previous attempts has been made in the field of vulnerability assessment (due to large resemblance with safety risk assessment) [10-12] whereas few efforts have been devoted to the estimation of attack likelihood [13].

Irrespective of whether it has been the former or the latter, the general assumption overarching the entire assessment has usually been the similarity of consequences with those of safety events such as accidental release of chemicals. At the top, such studies have only bothered to mention that in the case of terrorist attacks the consequences, especially in terms of human casualties, are expected to be by far severer and larger compared to safety events. However, to the best knowledge of authors, studies devoted to investigate the extent and severity of security events' consequences have been very scarce, if any.

Consequence analysis in cases of safety (Figure 3(a)) and security (Figure 3(b)) issues has been performed in ALOHA [14] and been displayed in Figure 3, in which an accidental release of chlorine from a pressurized cylinder can cause severe effects on-site (red contour) but minor impacts offsite (yellow contour) whereas an intentional simultaneous detonation of several such cylinders can affect a large residential area offsite which is quite incomparable in terms of extent and severity.

Figure 3. (a) Consequences assessment for a safety event: a leak from a small hole in a chlorine cylinder. (b) Consequences assessment for a security event: detonation of several chlorine cylinders. The contours denote: Red= ERPG-3 (20 ppm); Orange: ERPG-2 (3 ppm); Yellow= ERPG-1 (1 ppm).

Apart from human casualties, the consequences a safety event in terms of replacement costs and economic damages do not compare with those of a security event. Figure 4(a) depicts the affected area due to a pool fire caused by an accidental leakage from a hole in a storage tank while Figure 4(b) illustrates the affected area of the same chemical plant caused by the detonation of a VBIED (vehicle born improvised explosive device).

Figure 4. (a) Consequences assessment of a safety event: pool fire due to an accidental leak from a in an ammonia storage tank. (b) Consequences assessment of a security event: detonation of a VBIED in the ammonia storage area. The red contour denote a heat radiation intensity of 15 kW/m^2 which is high enough to cause damage to atmospheric storage tanks.

In the consequences analyses of Figures 3 and 4, we purposely have not provided detail information on the potential attack scenarios (the amount of improvised explosive, the location of detonation, the weather conditions, the size of rupture, etc.) in fear of providing food of thought for potential perpetrators.

2.4. Communication: sharing information and knowledge

The swift advances of sharing information and communication technology in recent years has seen knowledge management become a key tool for the success of an organization. Many international organizations have developed various programs and activities on chemical risk management and mitigation practices preventing chemical accidents and potential misuse of chemicals which plays a pivotal role as key to their future expansion strategies. International organizations such as OPCW, The United Nations Economic Commission for Europe (UNECE), The Organization for Economic Co-operation and Development (OECD), United Nations Office for Disarmament Affairs (UNODA), etc. have identified knowledge and information sharing as one of their primary management tools to overcome current threats posed by non-State actors on chemical facilities. The result is the rapid expansion of information sharing and knowledge dissemination activities among Member States specifically targeting government and private sector officials who track and oversee the legitimate uses of chemicals of interest.

Despite the increasing popularity among the scientific and non-scientific community, sharing information and knowledge dissemination related to risk assessment and management strategies, during workshops and seminars remain a complex and challenging task. It creates specific challenges as States Parties have adopted different risk management strategies to cater to their individual needs in diverse cultural settings. It has been evident that valuable resources have either been underutilized or duplicated, in the pursuit of developing better safety and security assessment tools. Therefore, adhering to a common integrated safety and security risk management plan would enable a common solution to overcome national boundaries across diverse cultural settings.

This seminar attempted to explicate the importance of a common safety and security risk assessment tool, which is accepted by Member States. The outcome of this forum illustrated the need to provide systematic processes to understand the risk related to chemical industries. In a future forum the objectives of the safety and security risk assessment programs would be accomplished through sharing of case studies, table top exercises and group discussions. It could explicitly define the roles and responsibilities of professional risk management teams, and identify results which could be leveraged for proper understanding of risk based safety and security assessment for Member States.

2.5. Data scarcity: application of precursors and data mining

Without a doubt, one of the most challenging parameters to estimate in security risk assessment is attack likelihood. A wide variety of factors should be taken into account in predicting the attack likelihood, including, but not limited to, (i) the general history of threats and attacks to similar targets – locally, regionally, nationally, and internationally – (ii) site-specific record of attacks, (iii) capability and potential actions of attackers (threats), (iv) motivation and intent of attackers, and (v) attractiveness of the chemical facility in the eyes of attackers [4], which in turn depends on a number of parameters the type of threat itself included (see the mutual interaction between "Threat" and "Attractiveness" in Figure 2(b)).

Apart from the foregoing complexities in predicting the attack likelihood, the issue of data scarcity arising from the rarity of terrorist attacks to chemical facilities has further limited the application of conventional frequentist approaches to likelihood estimation. In recent years, a number of techniques have been developed to make use of precursor data (indirectly relevant data) in reasoning and risk assessment of rare events where the amount of directly relevant data is not worthwhile [15-17] ; application of such precursor-based methodologies to, among others, nuclear plants' terrorist attack data (Figure 5) may be employed to infer chemical plants' security risks.

Figure 5. Spatial distribution of terrorist attacks to nuclear plants [18].

Besides the application of precursor data to estimate attack likelihood, data mining techniques can effectively be applied to analyze seemingly irrelevant security databases such as terrorist attacks on the public (e.g., in restaurants and movie theaters) (Figure 6) [1] so as to figure the trends in the activity, priorities, capabilities, and action plans of terrorist groups; such data bases due to data abundance can be used as a valuable source of information for (approximate) reasoning of attack likelihood. For one thing, the attack to a chemical plant in France in June 2015 [2] happened the same day as foreign tourists were murdered at a beach resort in Tunisia, and a suicide bomber attacked a mosque in Kuwait. It is yet unclear whether these events were correlated, although Islamic extremist groups were linked to all three [19].

Figure 6. Geographical distribution of public terrorist attacks [1].

In addition to the terrorist databases, the study and analysis of the correlation among the terrorist groups and organizations worldwide (Figure 7) [1] may provide useful information about possible activity of specific terrorist groups near a chemical facility of interest and the likelihood of an imminent attack.

According to Figure 7, for instance, the two terrorist organizations Al-Qaida and Pakistani Taliban, both denoted as yellow squares, are being considered as allied [1]; as a result, the changes in the policies or intent of one can be taken as an implication of the other's. Likewise, The Islamic State of Iraq and Sham (ISIS) and The Afghan Taliban, both denoted as red squares, have been recognized as conflicting groups [1], in that, the presence of one in a region implies the absence or low activity of the other in the same region.

Figure 7. Correlation among terrorist organizations worldwide [1]. Re: Religious terrorist groups; Se: Separatist terrorist groups; En: Ethnic terrorist groups.

2.6. Chemical clusters

The challenges faced in the security risk assessment of (individual) chemical plants seem to be more difficult yet crucial to tackle in chemical industrial areas – a.k.a chemical clusters – where a number of chemical plants are technically, managerially, or operationally (either structure-wise or information-wise) dependent on one another or share common interests or at least share common premises. In such chemical clusters, on top of the complicated interactions among the parameters of security risk assessment (threat, attractiveness, vulnerability, etc.), there lie structural and infrastructural dependencies and interdependencies within the chemical cluster which should be taken into account when assessing and managing the security risks [20,21].

In this regard, application of precursor-based dynamic risk assessment (PDRA) methodologies can remarkably be of interest in which security precursor data in a chemical plant (e.g., observation of a hole in the perimeter fence or a reported intrusion) can be used to assess and update the level of security risk both in the affected chemical plant and the entire cluster. Figure 8(a) depicts a conceptual model of this kind where a Bayesian network (BN) [22] is used to model the interaction not only among the components of individual chemical plants (the nodes of the same color along with the solid arcs) but also the dependencies among the chemical plants of the cluster (denoted by dashed arcs). Figure 8(b) displays the same BN has been extended to an influence diagram through which multi-criteria decision analyses such as cost-benefit analysis [23] or risk-based decision making [24] can be performed for, for instance, optimal allocation of countermeasures subject to limited available resources.

Figure 8. (a) Bayesian network for security risk assessment in a chemical cluster. (b) Influence diagram for performing multi-criteria decision analysis.

No to mention that, in such a dynamic framework even safety precursor data such as accidental loss of containment, fires, or explosions can be used as indicators to infer the performance and efficiency of barriers, preparedness of employees and emergency response teams, and thus the vulnerability of the plant (and cluster) to intentional events. It is worth noting that the application of PDRA is not limited merely to chemical cluster but can be of great interest in individual chemical facilities as well.

2.7. Inherently safer design techniques

The concept of Inherent Safety or Inherently Safer Design (ISD) was first introduced by Professor Trevor Kletz (1922-2013) following the Flixborough disaster in UK in 1974 [25]. "ISD is not a tool but a philosophy and way of thinking" (Dennis Hendershot, during a speech for CSB [26]) which is aimed at eliminating the hazard instead of trying to control it or to mitigate the consequences. Kletz' famous quote "What you don't have, can't leak" [25] have been interpreted via five themes [27]: (i) minimization, and (ii) substitution of hazardous materials and/or processes with less hazardous ones, (iii) moderation of process parameters such as temperature and pressure (iv) simplification of processes, and lately (v) limitation of effects, via, for example, separation distances between critical units (e.g., storage area and control rooms).

The benefits of ISD in security risk assessment can be many folds. For instance, by minimizing or substituting hazardous materials, not only the attractiveness of chemical plants as a potential target is diminished but also in case of an attack the extent and severity of consequences would be minor. Since security risk (SR) can be defined as a multiplicative function of threat (T), attractiveness (A), vulnerability (V), and consequences (C) [5], SR= T. A. V. C (see Figure 2(a)), a reduction in the attractiveness and consequences will result in a reduction of security risk.

Besides, through simplification of process (e.g., neat and easy-to-monitor pipeline and valves), an intentional release of chemicals is much likelier to be noticed and followed by timely preventive and controlling measures. Similar beneficial attributes can be gained from limitation of effects (for example, via safety distances between critical units) where an intentional loss of containment and possible ensuing fire or explosion is less likely to escalate to secondary fire or explosions in neighboring units, initiating a domino effect.

2.8. Land use planning

Similar to ISD, land use planning (LUP) is a no-structural safety measure aimed at mitigating offsite consequences of major accidents by protecting people from exposure to dangerous doses generated by fire (heat radiation), explosion (overpressure), and especially dispersion of toxic materials (toxicity). In LUP, the land around either a major hazard installation such as a chemical facility or hazardous pipeline such as oil & gas pipeline is divided to zones usually based on the severity of potential consequences of possible accident scenarios (consequence-based LUP) or amounts of individual or societal risks (risk-based LUP).

Figure 9 exemplifies a risk-based LUP practiced in UK [28] where the boundaries of inner zone (IZ), middle zone (MZ), and outer zone (OZ) are determined with individual risks corresponding to 1.0 E-05, 1.0 E-06, and 3.0 E-07, respectively. Based on the amount of individual risk (probability of death as a result of exposure to lethal dose) and vulnerability of users (manufacturer employees, primary schoolers, etc.) there can be advice against (AA) or no advice against (NAA) activities/developments in each zone (Table 1).

Terrorist attacks are usually launched with the aim of causing mass casualties and spreading the feeling of panic in the society and drawing media attention; as such, considering a chemical facility merely in form of a tool for manslaughter (excluding in this case the possibility of stealing chemical agents or business information), LUP can effectively not merely reduce the attractiveness of the facility in the eyes of terrorist groups but also alleviate the extent and severity of consequences at least in terms of loss of lives and environmental damages (in case the environment itself is considered in LUP as a vulnerable user).

Figure 9. Risk-based land use planning [28].

Table 1.

The majority of relevant work over the past two decades as to the role of LUP in safety assessment and (safety) risk-based design/decision-making of chemical facilities (e.g., see [29]) has been inspired by the EU Council Directive 96/82/EC, a.k.a Seveso Directive II [30].

Articles 12 of the Seveso II [30] explicitly mandates the EU Member States to consider LUP for the limitation of major hazards consequences to man and the environment. Article 12 is mainly devoted to (i) sitting of new installations, (ii) modification to existing installations, and (iii) land developments in the vicinity of existing installations, particularly those developments which would increase either the population at risk or the severity of the risk. In other words, it does not apply to an existing installation unless there are any internal modifications to the plant or external land developments in the vicinity of the plant. However, to the best knowledge of the authors, the inclusion of security risks in LUP has not been considered as yet, which otherwise can remarkably reduce the severity of offsite consequence of intentional events and thus lessen the attractiveness of the facility.

3. Conclusions

We argue that physical security still has a long way to go in the chemical and process industry, and that the field is still in its puberty, in industrial practice. New paths need to be walked on by academia and by industrial practitioners since 9/11 since the world has profoundly changed – and is still changing – in terms of terrorism, interconnectedness of people, communication and social media, technological progress (e.g., drone technology), ethical and moral values (e.g. transparency and privacy). Despite all the progress and advancement achieved in communication techniques, big data and internet of things, issues such as education and ethics, exchange of information, and data scarcity need to effectively and innovatively be addressed in an adult way (e.g., how to solve the trade-off 'transparency-privacy') in the domain of security risk assessment.

Safety insights and progress can indeed be used to steer basic security progress, but more is needed. The challenges and trends that we discussed in this paper show that security risk assessment and management in chemical plants can and should really take a leap forward in the near future in order to prevent from major terrorist attack on chemical industrial sites. As pointed out by Jochum [31], "it seems too optimistic to think we could eliminate terrorist groups or even stop them from carrying out terrorist attacks. What we can do is stop them from turning our own infrastructure against us to cause mass casualties." Safety concepts such as inherent safety and land use planning can effectively be adopted in security risk assessment to reduce attractiveness and vulnerability of chemical facilities from one hand, and the severity of envisaged consequences from the other hand .

Appendix: Chemical Safety & Security education in the Chemical Institute at University of the Philippine

Herein, a special course – Chemistry 359 – offered in the Institute of Chemistry at University of the Philippines-Diliman on chemical safety and security will be discussed as an example of an activity, which can be categorized under education and training in security risk management (see Section 2.2). The example includes the design of the syllabus and topics, sequence of topics, as well as the kind of tools employed for student performance assessment.

The main objective of the course is to teach an introductory subject on chemical safety and security to licensed chemical practitioners who are taking their master's degree in Chemistry at University of the Philippines, whether they are working as chemists in private companies, research and development chemists in the government, or chemistry instructors. This was the chosen audience for the lectures as they already have a solid foundation on chemistry and chemical reactions, which is prerequisite to the discussion of chemical safety. In addition, these chemists are actually practicing chemistry in their line of work.

The course starts with lessons on ethics involving the use of chemicals. This topic was given strong emphasis, as the learning outcome is quite lofty, which is to help develop and instill a sense of moral compass or "chemical conscience" in chemical practitioners. As already mentioned, the significance of this topic lies not only in mitigating possible insider-involvement security breaches in the workplace, but to teach chemists how to practice chemistry ethically such as identifying possible consequences that may affect the public and environment as a result of their practice. The code of conduct for chemists was included in this segment following the requisites given by the American Chemical Society [32].

The dual-use of chemistry, which looks at specific chemicals with multiple uses, and may have possible nefarious applications such as warfare and substance abuse were also included in this segment [33] Award-winning scientists with checkered reputations such as Fritz Haber were talked about in class, emphasizing the need for ethics in the practice of chemistry, for it to be beneficial to humanity. It was also made clear that the intention of the practitioner is everything, and will decide whether chemistry becomes a friend or foe. The philosophy behind the science of chemistry and its practice was also included, even looking at the nature of the science itself [34].

As an output for this topic, the students were expected to write a report on the dual-use of chemistry on a chemical of their choosing. The report included the history of the compound chosen, such as how it was discovered, reactions that the chemical may undergo for it to become hazardous, events on when the compound was used nefariously, and laws that govern the use of the compound.

Chemical safety was discussed before chemical security to rehash the students on their safety knowledge taken during their undergraduate laboratory courses. This was also deemed necessary for the students to understand better chemical security. This specific topic involved laboratory safety such as PPE, chemical compatibilities for proper storage, chemical safety logos and labels, chemical spill management, and pollution prevention and waste minimization. Emergency safety placements were also emphasized such as “buddy system” and “safety network”.

For safety in the chemical plants, governing laws and implementing rules and regulations on occupational health, safety, and the environment were discussed, including environmental monitoring and analyses specific to a particular chemical plant, maintenance and inspection, as well as safety in transporting chemicals [35]. Most of the materials used are based on the protocol of chemical plant safety prepared by the Mitsubishi Gas Company in Japan [36].

Chemical security on the other hand, was focused on physical protection, transport management, and cybersecurity. The materials used for discussion were mostly taken from the modules prepared by Sandia National Laboratories under the Chemical Security Program of the United States of America [37].

For safety risk assessment, only qualitative assessments were studied such as HAZOP, WHAT-IF analysis, and the basic risk equation due to the lack of expert in the institute. Models such as the Swiss cheese model and layer of protection model were also discussed. The concept of a core group in charge of safety and security assessment was highlighted to instill in the students the need for cooperation. Also, constant re-assessment of in place measures was emphasized as key to the success of risk management plans.

For the segment on chemical safety, the students performed exercises such as HAZOP, and What-if Analysis on specific chemical plant processes, identification of information processes and access controls specific to their workplace, as well as experienced-based approaches. There were three formal reports submitted for this topic, the first was on chemical safety risk assessment of an explosive or flammable chemical of their choosing. This includes the history and reactions of the compound, and the application of the Chemical Safety Risk Assessment and Self-Assessment Model (Chem-SAM), and HAZOP to the chosen compound [38]. The second report was on the use of safety labels in identifying chemical hazards, while the last one was on proper transport management including labels and packaging for a specific hazardous material identifying the mode of transport and route.

The last topic of the course was about the Organization for Prohibition of Chemical Weapons (OPCW) and the Chemical Weapons Convention (CWC). The current role of the OPCW in chemical safety and security was discussed, as well as the current status of the Philippines in terms of the implementation of the CWC [39]. The history of chemical weapons in warfare was also discussed as a way to introduce the CWC [40].

The students were asked to report on a specific article in the CWC and were asked to look for laws directly related to these articles, and the governing agencies responsible for the implementation of these laws in the Philippines. Another requirement on this segment was a report on case studies of actual plant disasters including cause analysis, and prevention analysis. The final examination was an online test on CSS using the developed web-based software eQChemSS of the OPCW [41].

The course was received with enthusiasm by the students as seen in their performance, and the results of the Student Evaluation Testing. It was able to provide them with an introductory course to chemical safety and security with emphasis on chemical ethics as a necessary principle to the practice of chemical safety and security in the workplace. The course will be very much improved if risk assessment experts will be on board, and actual application of the principles taught will be performed in chemical plants.

This course with the topics included may be a useful tool to CSS implementation, with possible impact to security risk management through education and training. The inclusion of lectures on the "ethics in the practice of chemistry" on CSS education and training may even prove vital in enhancing CSS implementation in the workplace such as in chemical facilities and plants.

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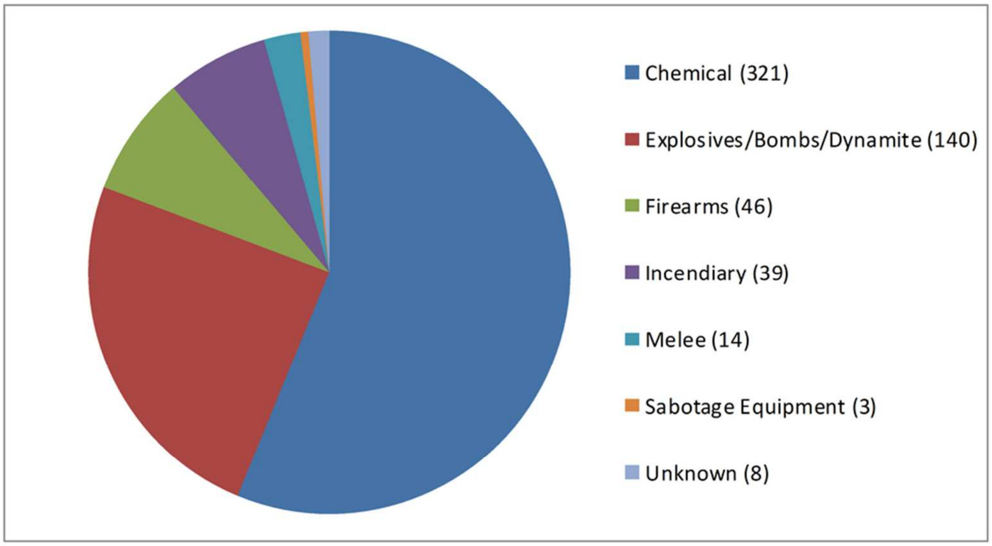
Table 1. Land use development based on the individual risk and user vulnerability [28].

Type of land use development	Zones in Figure 6		
	IZ	MZ	OZ
Factories with limited number of employees	NAA	NAA	NAA
Residential houses with limited number of residents	AA	NAA	NAA
Primary schools and nurseries	AA	AA	NAA
Airports, football stadiums, large hospitals	AA	AA	AA



Type of terrorist attacks worldwide in 2015 [1]

82x45mm (300 x 300 DPI)

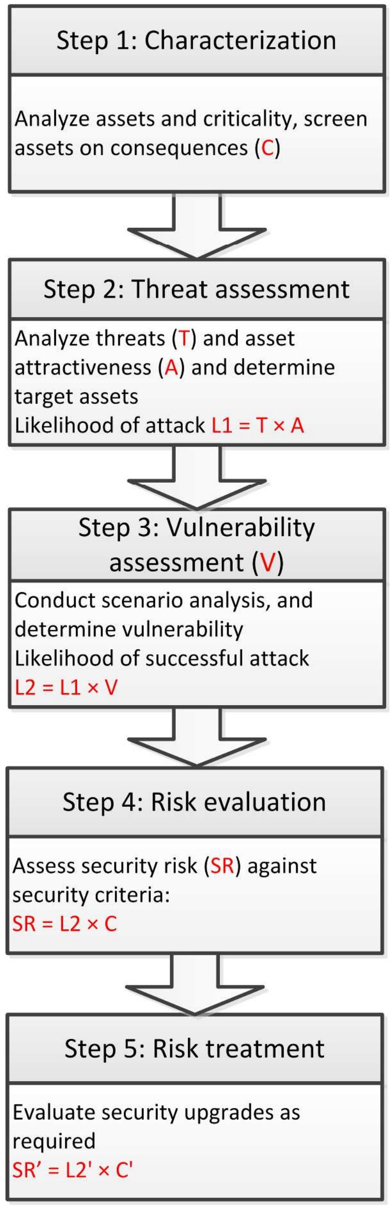


Figure 2 (a). API methodology [6] for security risk assessment.

175x545mm (300 x 300 DPI)

Figure 2(b). The interaction among the security risk parameters.

59x57mm (300 x 300 DPI)

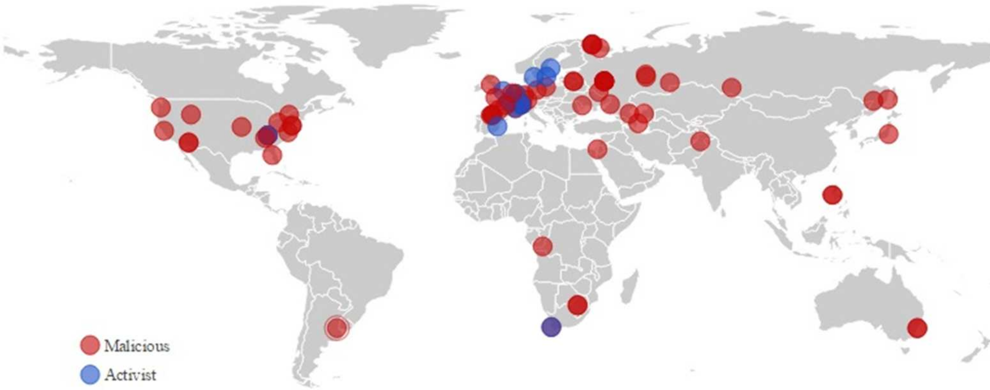


Figure 5. Spatial distribution of terrorist attacks to nuclear plants [16].

97x39mm (200 x 200 DPI)

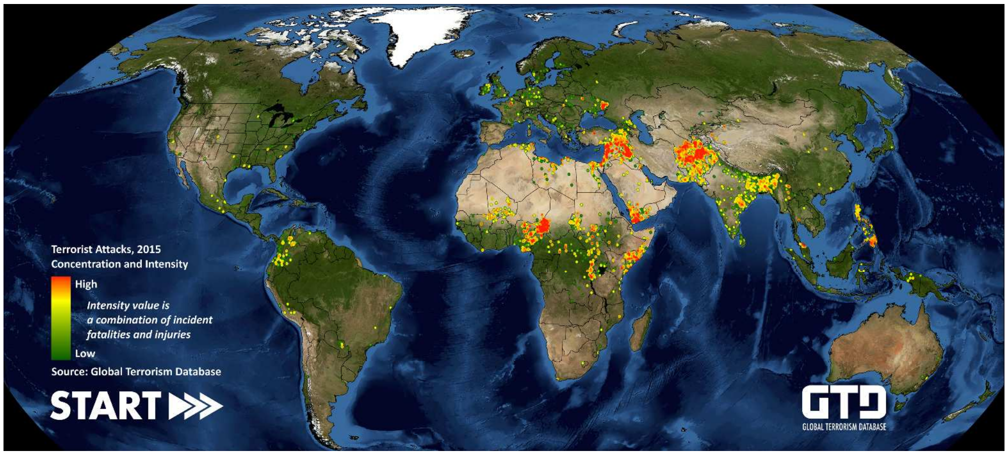


Figure 6. Geographical distribution of public terrorist attacks [1].

621x278mm (200 x 200 DPI)

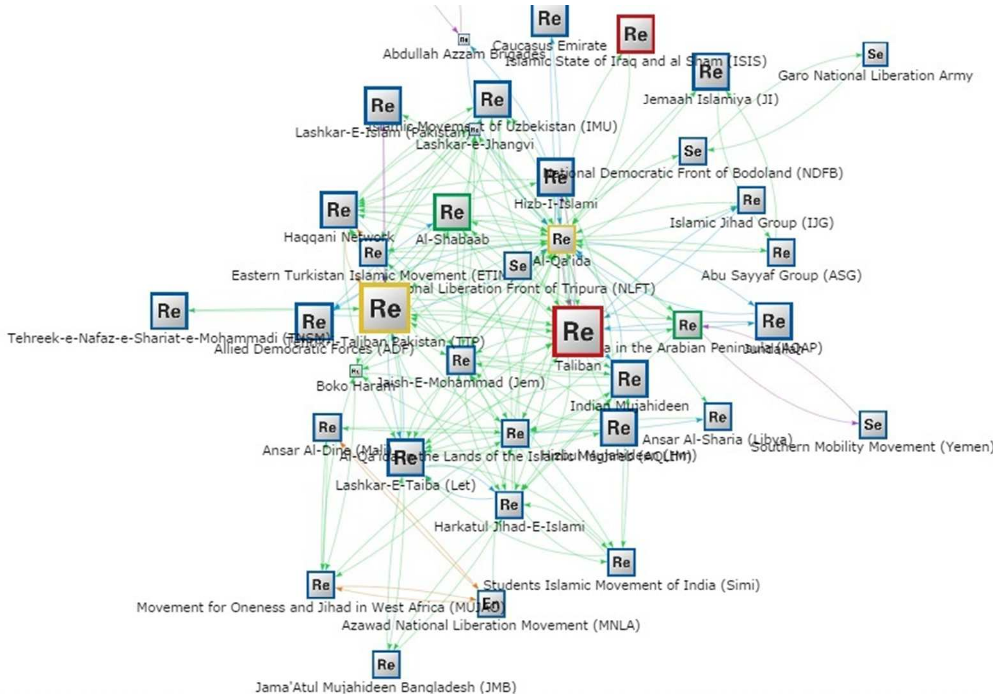


Figure 7. Correlation among terrorist organizations worldwide [1]. Re: Religious terrorist groups; Se: Separatist terrorist groups; En: Ethnic terrorist groups.

106x73mm (200 x 200 DPI)

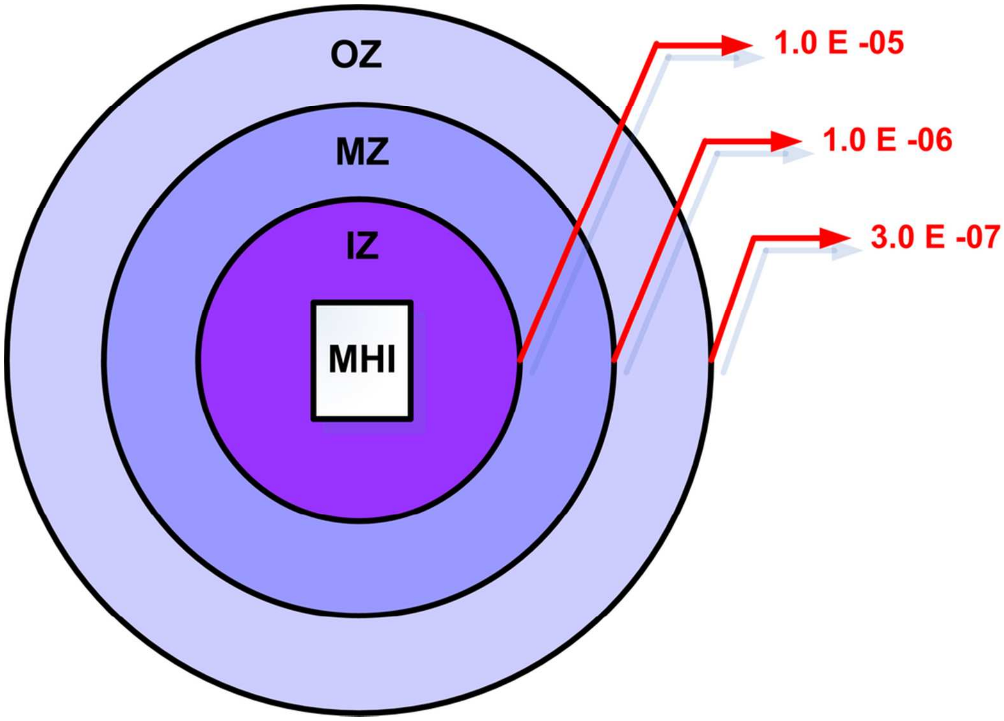


Figure 9. Risk-based land use planning [28].

92x66mm (300 x 300 DPI)

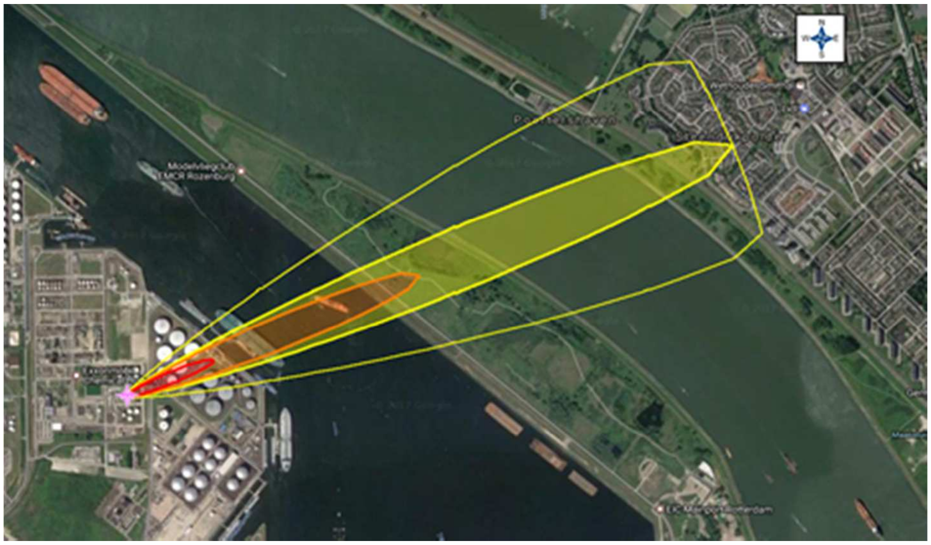


Figure 3 (a). Consequences assessment for a safety event: a leak from a small hole in a chlorine cylinder.

122x70mm (96 x 96 DPI)

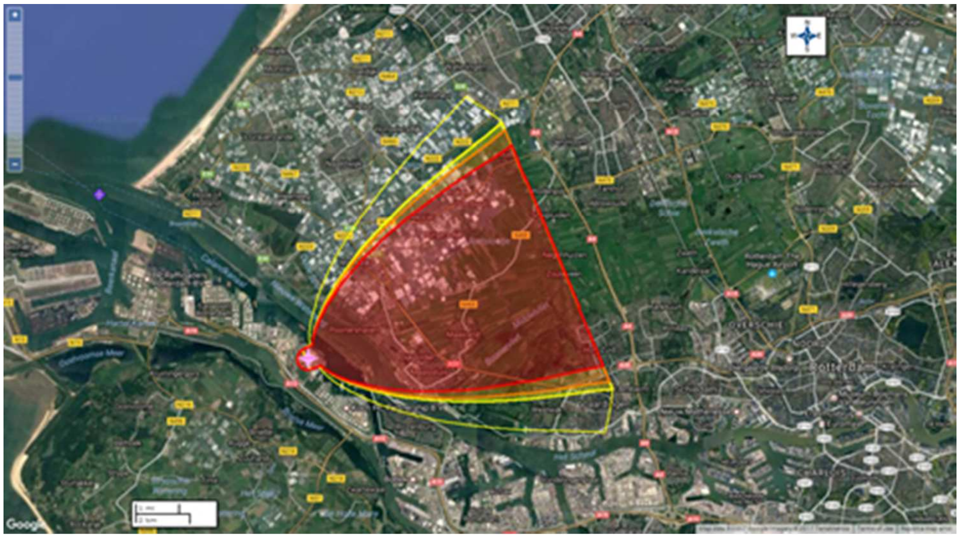


Figure 3 (b). Consequences assessment for a security event: detonation of several chlorine cylinders. The contours denote: Red= ERPG-3 (20 ppm); Orange: ERPG-2 (3 ppm); Yellow= ERPG-1 (1 ppm).

125x70mm (96 x 96 DPI)

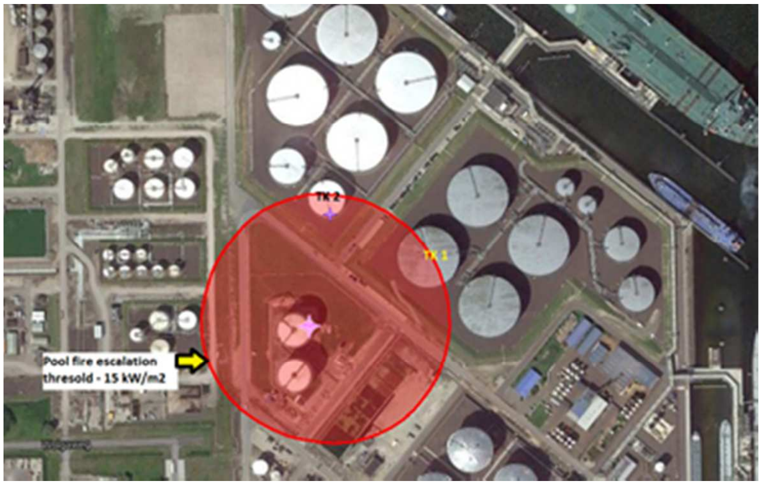


Figure 4(a). Consequences assessment of a safety event: pool fire due to an accidental leak from a in an ammonia storage tank.

99x62mm (96 x 96 DPI)

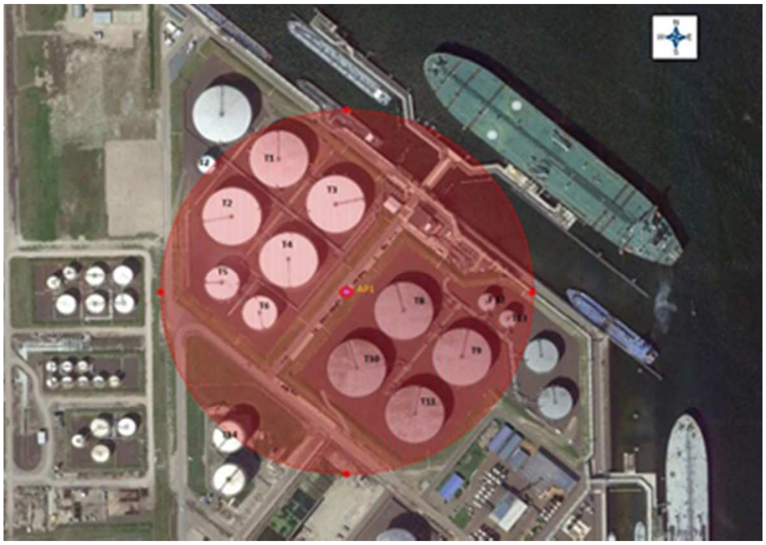


Figure 4(b). Consequences assessment of a security event: detonation of a VBIED in the ammonia storage area. The red contour denote a heat radiation intensity of 15 kW/m2 which is high enough to cause damage to atmospheric storage tanks.

100x70mm (96 x 96 DPI)

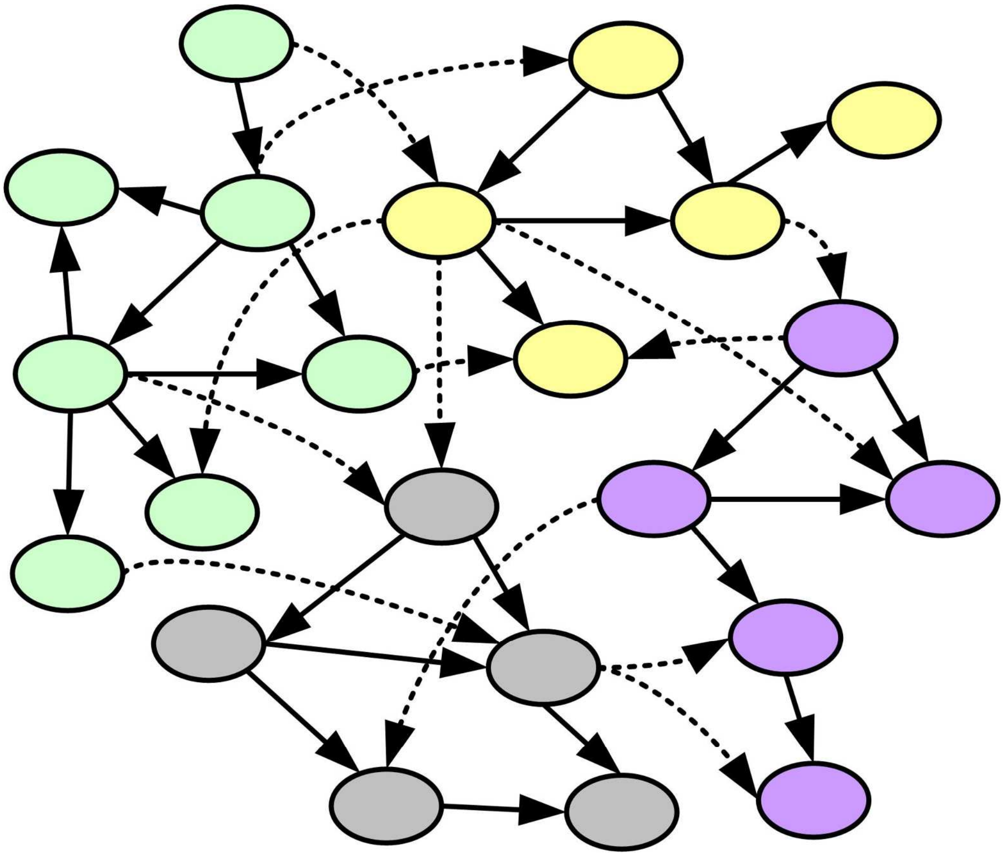


Figure 8(a). Bayesian network for security risk assessment in a chemical cluster.

247x210mm (200 x 200 DPI)

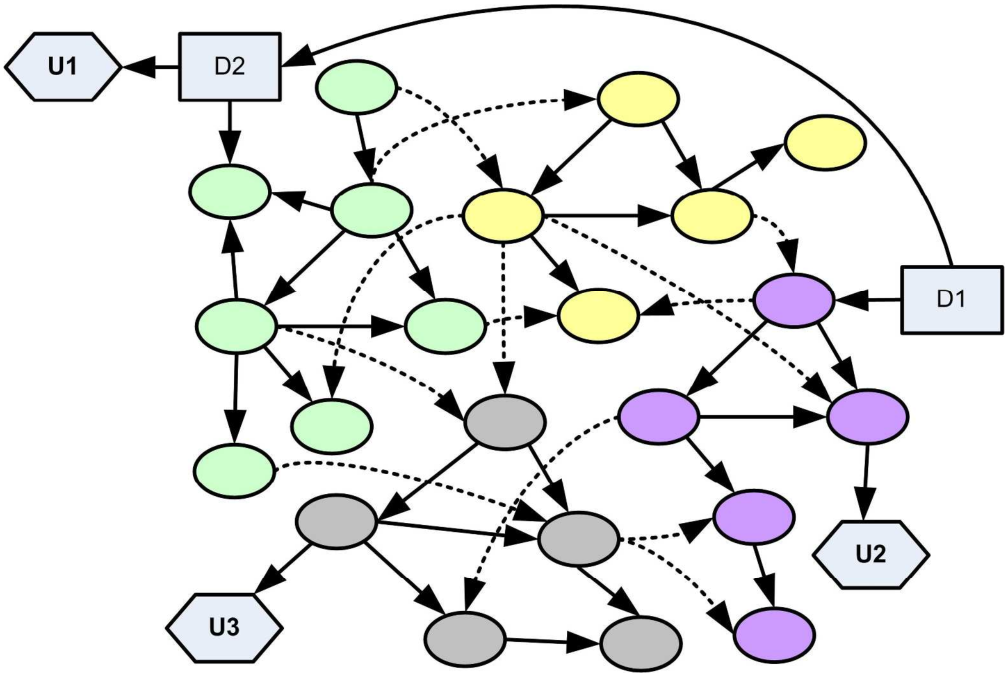


Figure 8(b). Influence diagram for performing multi-criteria decision analysis.

343x229mm (200 x 200 DPI)