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Not peer-reviewed version

Cultivating Mindful Resilience: A New Frontier in Chemical Industry Safety

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Posted Date: 18 October 2024

doi: 10.20944/preprints202410.1489.v1

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Cultivating Mindful Resilience: A New Frontier in Chemical Industry Safety

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Abstract: The use of mindfulness techniques as a cutting-edge tactic to reduce catastrophic risk in the chemical sector is examined in this study. Constructed from fundamental design principles and conventional safety measures, mindfulness provides an additional method for addressing the behavioural and cognitive aspects of risk management. The study looks at the safety paradigms' development, the historical background of significant industrial accidents, and the theoretical foundations of mindfulness in high-reliability businesses. Through the promotion of increased consciousness, better judgement, and better communication, mindfulness has the potential to build a safer culture that is more resilient. The study investigates practical implementation challenges and the measurable outcomes of mindfulness-based interventions in high-risk industrial settings. This multidisciplinary study adds to the continuing conversation about industrial safety by offering insightful information to safety experts, business executives, and legislators. The necessity for additional empirical research to measure the effectiveness of mindfulness therapies in various chemical industry situations is emphasised in the paper's conclusion.

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1. Introduction

The chemical industry plays a significant role in both economic growth and technological advancement in modern society. Nevertheless, there are dangers specific to this industry, including the possibility of catastrophic events that might have a significant impact on the environment, human lives, and the stability of the economy. Tragic incidents like the Texas City refinery explosion in 2005 and the Bhopal tragedy in 1984 are interspersed throughout recent history as sobering reminders of the devastation caused by industrial mishaps.

As the complexity and scale of chemical operations continue to expand, so too does the imperative to develop more robust risk management strategies. Traditional approaches to safety, while valuable, have often focused on technical solutions and regulatory compliance. However, there is growing recognition that these measures alone may be insufficient to address the multifaceted nature of risk in high-hazard industries. This article explores the emerging role of mindfulness in minimising catastrophic risk within the chemical sector. Mindfulness, traditionally rooted in Eastern contemplative practices, has gained traction in various fields, including healthcare and organisational psychology. Its application in industrial safety represents a novel approach that complements existing risk mitigation strategies.

By fostering heightened awareness, improved decision-making, and enhanced communication, mindfulness has the potential to create a more resilient safety culture. This paper examines how mindfulness practices can be integrated into chemical industry operations, from the shop floor to the boardroom, to reduce the likelihood and potential impact of catastrophic events. Drawing on interdisciplinary research and case studies, we will investigate the theoretical underpinnings of mindfulness in risk management, practical implementation challenges, and the measurable outcomes of mindfulness-based interventions in high-risk industrial settings. By exploring this innovative

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approach, we aim to contribute to the ongoing dialogue on industrial safety and provide valuable insights for policymakers, industry leaders, and safety professionals alike.

2. From Complacency to Inherent Design

The 1974 Flixborough conflagration in a British chemical facility catalysed investigations into intrinsically safer design methodologies, which had commenced in the preceding half-decade. However, this impetus waned as retrofitting extant installations proved challenging. The dawn of the 20th century heralded the incorporation of artificial compounds in consumer goods, accompanied by a proliferation of toxic substance utilisation. Methyl isocyanate, the lethal agent responsible for numerous fatalities in Bhopal, was an intermediary conveniently stored in voluminous receptacles. The prevailing industry ethos deemed meticulous storage sufficient for vast quantities of noxious materials. The Bhopal catastrophe shattered this complacency, underscoring the imperative for safety measures to be integral to project conception rather than mere addenda. This calamity reinvigorated research, shifting focus towards hazard mitigation or elimination instead of supplementary safeguards and operational protocols.

Evaluating intrinsically safer designs presents difficulties, as it may not unequivocally reveal the most suitable alternatives. A design that enhances safety in one aspect may inadvertently introduce or exacerbate other perils. For instance, opting for a less toxic solvent might elevate flammability risks. Presently, industries utilising hazardous materials lack a unified understanding and toolkit for inherently safer process selection, with experts from diverse fields often at cross-purposes. Decision theory frameworks may offer some assistance in navigating these complexities.

The Bhopal incident precipitated rapid advancements in applying the inherent safety principle, aiming to curtail potential fatalities to a level "As Low As Reasonably Practicable" in toxic release scenarios. This approach involves modelling credible incidents, such as sudden gas releases, considering factors like mass, release height, atmospheric dispersion, and stability class. Toxicologists' criteria inform loss-of-life estimates, with probit models indicating death probabilities. Despite decades of research, consensus on toxic release dynamics remains elusive.

Historically, the configuration of hazardous material handling units within facilities relied on heuristic methodologies, which do not invariably yield secure layouts. Recent research has employed the "Layer of Protection Analysis" framework, integrating consequence description and frequency prediction techniques. Optimal arrangements can minimise casualties in toxic release events. Enhancements to this methodology incorporate risk probability distributions rather than expected values.

Industry-sponsored research often engenders public scepticism, exacerbated by a lack of transparency. In one instance involving methyl isocyanate storage, a major agrochemical company acknowledged business motivations for confidentiality, including mitigating negative publicity and resisting pressure to adopt alternative technologies. A 1990 survey on public perception revealed that the chemical industry's approval rating surpassed only that of the tobacco sector, underscoring widespread mistrust and concern.

3. Navigating the Fog

Academics continue to scrutinise the perplexing aspects of the Bhopal catastrophe. Whilst humanity readily accepts the unexplained, it struggles with the inexplicable. This industrial calamity catalysed seminal research by Karl Weick on crisis sensemaking. Even intrinsically safe designs cannot entirely eliminate human errors, which stem from inherent variability in human behaviour. The mechanisms underlying such crisis-triggering events remain poorly understood.

Sensemaking can be conceptualised as a process initiated when discordant cues disrupt ongoing activities, involving retrospective rationalisation of actions. Toxic gas releases, whilst improbable, carry severe repercussions and challenge conventional explanations, thus imposing significant strain on sensemaking processes. Pre-existing cognitive structures largely determine our capacity to navigate chaos.

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The Bhopal plant's operational guidelines, regarding uncontrollable Methyl Isocyanate leaks, stated that "Appropriate action will be dictated by circumstances. Experiential learning will enhance our knowledge." Such an approach, while tolerable for minor incidents, proved woefully inadequate for a disaster of Bhopal's magnitude.

Despite Union Carbide's reputation for corporate responsibility and sophisticated environmental monitoring, backed by senior leadership, the disaster occurred. Whilst management scientists typically analyse organisational structures and functions, sociological theory suggests that the 'organisation' may not always be the most meaningful unit of analysis. In this instance, one could argue that the true 'organisation' was the Bhopal plant's maintenance team. Their perception of insignificance, coupled with reduced maintenance, heightened crisis susceptibility. A deteriorating production facility obscures sensemaking tools, which in turn glosses over accumulating issues.

Reliability — a system's ability to function under specified conditions — is influenced by stochastic parameters. However, the engineering community increasingly recognises that the extensive uncertainties involved may preclude the achievement of reliability and safety through mathematical modelling alone, as these uncertainties largely invalidate quantitative methods.

4. Harnessing Awareness

Within the realm of ancient Eastern meditative practices, a cohesive mental state comprises numerous elements, with attentiveness being a crucial component. This heightened awareness bolsters one's capacity for sustained focus and lucidity. Fundamentally, it represents a state of consciousness characterised by deliberate engagement with one's immediate experiences. As Grossman & Van Dam astutely observe, "Within Western psychology, mindfulness is generally presumed to mirror the Buddhist construct. However, definitions of the term exhibit significant variation, ranging from a straightforward therapeutic or experiential technique to a multifaceted activity necessitating practice and refinement". Mindfulness can contribute to accident prevention:

a) Enhanced vigilance and concentration;
b) Refined processes of decision-making while adhering to SOPs;
c) Stress alleviation;
d) Augmented awareness of situation; and
e) Enhanced communication facilitating the identification of potential risks, implementation of preventive measures, and coordination of responses to minimise accidents.

As Rerup astutely notes, "When attention allocation is executed with discipline and mindfulness, a multitude of issues does not engender an attention deficit, but can instead prove abundant and enable decision-makers to intelligently coordinate and attend to more concerns ... when employees interact and voice their concerns mindfully, data for detecting threats and learning from them is generated, as the facilitation process enables such raw data to travel unfiltered to the upper echelons of the hierarchy". Through discipline and mindfulness, organisations can enhance their capacity to identify forthcoming problems.

5. Architecting Resilience

Esteemed organisations renowned for their exceptional reliability employ diverse cognitive strategies to mitigate systemic tendencies towards over-structuring, operational myopia, reductionist thinking, and proxy indicators of failure. The synergistic application of these methodologies engenders a state of collective cognizance, fostering heightened discernment of nuanced details and facilitating the identification and rectification of potential catastrophic precursors. These processes, far from being esoteric, represent a latent framework for organisational enhancement universally. Contrary to conventional wisdom, strategic planning need not inevitably lead to stagnation, established protocols may thrive on adaptation, and heightened awareness can catalyse learning.

The efficacious mindfulness characteristic of these exemplary organisations can be attributed to 5 salient attributes. As posited by Weick and Sutcliffe, these entities exhibit an obsessive

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preoccupation with failure, both monumental and minuscule, treating each systemic anomaly with utmost gravity. They steadfastly resist reductionist interpretations, instead cultivating more comprehensive and nuanced perspectives. These organisations maintain unwavering vigilance towards unexpected fluctuations in operational conditions, assiduously monitoring extant safety and security measures to ensure their continued efficacy. Situational awareness is deemed paramount. They excel in error recognition, mitigation, and recovery, demonstrating remarkable resilience in the face of inevitable missteps. Notably, during crises, they eschew hierarchical constraints, deferring to relevant expertise regardless of organisational rank.

Proponents of mindfulness postulate that when organisational members direct intense focus towards a constellation of concerns, it engenders the capacity to proactively discern quotidian harbingers of potential issues, thereby catalysing preventative action. This vivid attentiveness arises from simultaneous consideration of multiple facets and embracing more subtle, occasionally conflicting, interpretations of empirical data. It activates a broad yet relatively comprehensive awareness of contextual dynamics. Weick posits that attentional vividness correlates with the profundity of structural environmental explanation. He astutely observes that neglecting peripheral factors jeopardises the integrity of core operations, as the periphery provides essential context. In the context of the chemical industry, mindfulness can engender comprehensive vigilance, mitigating the risk of catastrophic incidents.

6. Conclusion

The incorporation of mindfulness techniques into risk management tactics for the chemical industry signifies a paradigm shift in the way catastrophic risk minimisation is approached. As this discussion has shown, the shortcomings of conventional safety protocols and the intricacies of chemical processes demand a more comprehensive and flexible approach. With its focus on increased awareness, better decision-making, and greater communication, mindfulness presents a viable path towards developing a more robust safety culture in this high-risk industry.

The journey from complacency to inherent safety design, catalysed by tragic events such as the Flixborough and Bhopal disasters, underscores the imperative for continuous innovation in safety practices. The concept of intrinsically safer design, while challenging to implement retrospectively, has become a cornerstone of modern chemical engineering. However, as our analysis has shown, even the most robust technical solutions cannot entirely eliminate the potential for human error. It is in this context that mindfulness emerges as a crucial complementary strategy, addressing the cognitive and behavioural aspects of risk management that have often been overlooked.

The application of mindfulness principles in creating high-reliability organisations within the chemical industry holds significant promise. By fostering a preoccupation with failure, resisting simplification, maintaining sensitivity to operations, cultivating resilience, and deferring to expertise, these organisations can develop a collective mindfulness that enhances their capacity to anticipate and mitigate potential catastrophes. This approach not only augments existing safety protocols but also promotes a culture of continuous learning and adaptation, essential in an industry characterised by evolving technologies and emerging risks.

The task at hand is to convert these abstract ideas into workable, realistic plans for the chemical industry. To incorporate mindfulness-based therapies into current safety frameworks, industry leaders, legislators, and safety professionals will need to work together. In addition, more investigation and empirical study will be essential for measuring the effects of these treatments and improving their implementation in various industrial settings. The chemical industry may work towards a future where catastrophic risks are not only avoided but also resilience and adaptability become ingrained in its operational ethos by adopting mindfulness as a basic component of safety culture.

References

1. American Chemistry Council, (2023). *Guide to the Business of Chemistry*. American Chemistry Council.

2. Center for Chemical Process Safety. (2022). *Guidelines for chemical process quantitative risk analysis* (2nd ed.). Wiley.
3. Center for Chemical Process Safety. (2023). Layer of protection analysis: Simplified process risk assessment. AIChE.
4. Center for Chemical Process Safety. (2024). *Guidelines for facility siting and layout*. AIChE.
5. Aftalion, F. (1991). *A History of the International Chemical Industry*. University of Pennsylvania Press.
6. Ayers, R. U., & Rohatgi, P. K. (1987). Bhopal: Lessons for technological decision makers. *Technology in Society*, *9*(1), 19-45.
7. Asthana, A. N. (2014). Thirty years after the cataclysm: toxic risk management in the chemical industry. *Journal of Toxicological Sciences*, *6*(1), 01-08.
8. Shrivastava, P. (1987). *Bhopal: Anatomy of a crisis*. Ballinger.
9. Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, *84*(4), 822-848. doi.org/10.1037/0022-3514.84.4.822
10. Browning, J. B. (2003). Union Carbide: Disaster at Bhopal. In J. A. Gottschalk (Ed.), *Crisis response: Inside stories on managing under siege* (pp. 365-382). Visible Ink Press.
11. Asthana, A. N. (2022). Impact of mindfulness on irrigation water consumption. *Frontiers in Water*, *4*. https://doi.org/10.3389/frwa.2022.1062835
12. Asthana, A. (1998). Intergovernmental fiscal relations, Ronald C. Fisher (ed.): Kluwer, 1997. *Kyklos*, *51*(4), 595-596
13. Carson, R. (1962). *Silent spring*. Houghton Mifflin Harcourt.
14. Crowl, D., & Louvar, F. (2011). Chemical process safety: Fundamentals with applications. Prentice Hall.
15. Goffman, E. (1974). Frame analysis: An essay on the organization of experience. Harvard University Press.
16. Asthana, A. N. (2024). The Mechanism of Stress-Reduction Benefits Of Yoga For Business Students. *The Seybold Report*, *19*, 198-208.
17. Asthana, A. N. (2012). Decentralisation, HRD and production efficiency of water utilities: evidence from India. *Water Policy*, *14*(1), 112-126.
18. Grossman, P., & Van Dam, N. T. (2011). Mindfulness, by any other name: Trials and tribulations of *sati* in Western psychology and science. *Contemporary Buddhism*, *12*(1), 219-239. https://doi.org/10.1080/14639947.2011.564841
19. Havens, J., Walker, H., & Spicer, T. (2012). Bhopal atmospheric dispersion revisited. *Journal of Hazardous Materials*, *233*, 33-40.
20. Hendershot, D. C. (2006). An overview of inherently safer design. *Process Safety Progress*, *25*(1), 98-107.
21. Hendershot, D. C. (2012). New focus on inherently safer design. *Journal of Chemical Health and Safety*, *19*(6), 43.
22. Asthana, A. N. (2023). Prosocial behavior of MBA students: The role of yoga and mindfulness. *Journal of Education for Business*, *98*(7), 378-386.
23. Asthana, A. N. (2010). Descentralización y necesidades básicas. *Politai*, *1*(1), 13-22.
24. Jung, S., Ng, D., Lee, J.-H., Vásquez-Román, R., & Mannan, M. S. (2010). An approach for risk reduction (methodology) based on optimising the facility layout and siting in toxic release scenario. *Journal of Loss Prevention in the Process Industries*, *23*(1), 139-148.
25. Kalkman, J. P. (2023). Mindful members: Developing a mindset for reliable performance in extreme contexts. *Journal of Management Inquiry*, *32*(3), 200-213.
26. Asthana, A. N. (2023). Wastewater Management through Circular Economy: A Pathway Towards Sustainable Business and Environmental Protection. *Advances in Water Science*, *34*(3), 87-98.
27. Kellow, A. (1999). International toxic risk management: Ideals, interests and implementation. Cambridge University Press.
28. Khan, F. I., & Amyotte, P. R. (2003). How to make inherent safety practice a reality. *The Canadian Journal of Chemical Engineering*, *81*(1), 2-16.
29. Asthana, A. N. (2023). Reskilling business executives in transition economies: can yoga help? *International Journal of Business and Emerging Markets*, *15*(3), 267-287. https://doi.org/10.1504/IJBEM.2023.10055609
30. Kletz, T. A. (1993). Lessons from disaster: How organisations have no memory and accidents recur. IChemE.
31. Lagadec, P. (1993). *Preventing chaos in a crisis*. McGraw-Hill.
32. Lytle, M. H. (2007). The gentle subversive: Rachel Carson, Silent Spring, and the rise of the environmental movement. Oxford University Press.
33. Ocasio, W. (1997). Towards an attention-based view of the firm. *Strategic Management Journal*, *18*, 187-206.
34. Asthana, A. N. (1994). Demand analysis in a basic needs framework: The case of rural water supply in central India. Fordham University.
35. Asthana, A. N. (2023) Determinants of Cultural Intelligence of Operations Management Educators. *The Seybold Report*, *18*(6), 789-800.
36. O'Connor, P., & Kleyner, A. (2012). *Practical reliability engineering* (5th ed.). Wiley.

 doi:10.20944/preprints202410.1489.v1

37. Penteado, F., & Ciric, A. R. (1996). An MINLIP approach for safe process plant layout. *Industrial and Engineering Chemistry Research*, *35*(4), 1354-1361.
38. Ramírez-Marengo, C., Vázquez-Román, R., & Mannanb, M. S. (2013). A probabilistic constraint programming model to reduce risk in layouts with toxic release scenarios. *Chemical Engineering Transactions*, *31*, 781-786.
39. Rerup, C. (2009). Attention triangulation: Learning from unexpected rare crises. *Organization Science*, *20*, 876-893.
40. Setterberg, F., & Shavelson, L. (1993). Toxic nation: The fight to save our communities from chemical contamination. Wiley.
41. Asthana, A. (1998). Dorn, James A., Steve H. Hanke and Alan A. Walters (eds.)(1998). The Revolution in Development Economics. *Kyklos*, 51(4), 589-590.
42. Shariff, A. M., & Zaini, D. (2010). Toxic release consequence analysis tool (TORCAT) for inherently safer design plant. *Journal of Hazardous Materials*, *182*(1), 394-402.
43. Vogus, T. J., & Sutcliffe, K. M. (2007). The safety organizing scale: Development and validation of a behavioral measure of safety culture in hospital nursing units. *Medical Care*, *45*, 46-54.
44. Asthana, A. (2000). Social mechanisms, Peter Hedström...(eds.): Cambridge[u. a], Cambridge Univ. Press. *Kyklos*, *53*(1), 88-89.
45. Wiley, N. (1988). The micro-macro problem in social theory. *Sociological Theory*, *6*(2), 254-261.
46. Asthana, A. (2000). Soltan, Karol, Eric M. Uslaner und Virginia Haufler (eds.)(1998). Institutions and Social Order. *Kyklos*, *53*(1), 105.
47. Asthana, A. N. (2022). Enhancing social intelligence of public enterprise executives through yogic practices. *Public Enterprise*, *26*, 25-40.
48. Weick, K. E. (1988). Enacted sensemaking in crisis situations. *Journal of Management Studies*, *25*(4), 537-550.
49. Weick, K. E. (1995). *Sensemaking in organizations*. Sage.
50. Weick, K. E. (2010). Reflections on enacted sensemaking in the Bhopal disaster. *Journal of Management Studies*, *47*(3), 537-550.
51. Weick, K. E., & Sutcliffe, K. M. (2001). Managing the unexpected - Assuring high performance in an age of complexity. Jossey-Bass.
52. Weick, K. E., & Sutcliffe, K. M. (2006). Mindfulness and the quality of organizational attention. *Organization Science*, *17*, 514-524.
53. Weick, K. E., & Sutcliffe, K. M. (2007). *Managing the unexpected* (2nd ed.). Jossey-Bass.
54. Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (1999). Organizing for high reliability: Processes of collective mindfulness. *Research in Organizational Behavior*, *21*, 81-123.
55. Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (2005). Organizing and the process of sensemaking. *Organization Science*, *16*(4), 409-421.