An Actor-Network Analysis of the Unstable UCIL Pesticide Plant during The Bhopal Disaster

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The Bhopal disaster was a gas leak incident on the night of December 2nd of 1984 at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh, India. Approximately 30 tons of a highly toxic gas called methyl isocyanate (MIC) was stored there, as well as a number of other poisonous gases (Taylor, 2014). One of the three tanks responsible for storing MIC was malfunctioning and the tank filled up to higher than its allotted capacity, causing a runaway reaction (*What Was Bhopal Gas Tragedy, Cause of Bhopal Gas Tragedy, Bhopal Gas Tragedy News | Business Standard*, n.d.). The plant was surrounded by cottage towns which led to over 600,000 people being exposed to the deadly gas cloud the night of the release (Taylor, 2014). The gases managed to stay low to the ground which caused victims' throats and eyes to burn, and close to 4,000 people died (Taylor, 2014).

Those that have studied this case study believe that it is the culmination of several factors separately that led to the disaster; more specifically the technical failures and the lack of safety features. There exists little discussion as to the true connection of all the actors, human and non-human, that played a part in the destruction of the plant, which ultimately ruined the lives of hundreds of thousands of people. By analyzing the association of all of the actors, a dominant factor can be identified which will be held responsible. Furthermore, I claim that the major contributor to the Bhopal Incident is the poor management existing within the plant.

I will be examining the Bhopal case using actor-network theory (ANT) to analyze the aspects of an unstable pesticide plant which lead to the failure. More specifically, I will use ANT to argue that poor plant management is the dominant actor of any other mishaps that may have occurred that caused a network failure. Any disregard to safety and warnings, cost-cutting, and unskilled workers all lead to the incompetence of the management, the major actor that led to the

Bhopal disaster as we know it. To support my argument, I will analyze evidence from the primary documents and interviews made before and after the incident, which provides warnings for the plant, and clear disregard for safety to the actors in question.

Background

Methyl Isocyanate is a colourless liquid used for making pesticides. MIC is safe when maintained properly, however it is highly reactive to heat. When MIC is exposed to water, the compounds in MIC react with each other and cause a heat reaction (*What Was Bhopal Gas Tragedy, Cause of Bhopal Gas Tragedy, Bhopal Gas Tragedy News | Business Standard*, n.d.). Being exposed to high concentrations of MIC could result in severe damage to the lungs and can ultimately lead to death (*METHYL ISOCYANATE*, n.d.).

A runaway reaction is a thermally unstable reaction which shows an accelerating increase of temperature as well as reaction rate (Benintendi, 2018). Once control of the reaction is lost, the temperature can quickly rise without much time for reversal. The vessel that the reaction occurs in may be at a risk of over-pressurization which can lead to plant failure with a blast or release of chemicals. In the case of the Bhopal incident, this unstable runaway reaction is what resulted in the gas cloud of MIC that affected the surrounding neighborhoods of the plant.

Literature Review

There have been a substantial number of papers published discussing the Bhopal leak due to the sheer magnitude of the incident and the many difficulties that the surrounding communities went through. Many sources point responsibility for the disaster on a technical failure of the tanks and the overall lack of safety procedures in the plant. I will be looking into a few sources that have discussed the reason for the gas leak.

In *The Bhopal disaster and its aftermath: a review,* Edward Broughton points to several indications of equipment being used improperly (Broughton, 2005). There was clear evidence that the storage tank temperature for the MIC was not maintained during the disaster, which led to the high temperature chemical outburst (Broughton, 2005). He explains that a combination of under-maintained facilities and little to no regard for safety enabled water to penetrate the MIC tank. By underinvesting the safety in the plant, management helped develop the dangerous working environment. He also mentions the undersized safety devices and inadequate emergency response systems, which he argues as a major factor for the gas leak.

Similarly, CSB (U.S. Chemical Safety Board) investigations indicate that the systemic problems identified at Bhopal remain to be the underlying causes of many incidents (Joseph et al., 2005). This includes lack of awareness of reactive hazards, management of change, and ineffective employee training. They explore the many causes but do not place the responsibility on one specific group and do not explore how they affect each other. Managers and plant workers had little information on the hazard potential of the plant, like how the water contamination of the tanks containing MIC could create an uncontrollable chemical reaction (Joseph et al., 2005). A lack of adequate management of change (MOC) was one reason why those features were inoperative during the incident (Joseph et al., 2005). This source also mentions that an effective MOC program is critical to the safe operation of a chemical facility, but once again names several factors combined that could have been the cause of the incident.

There is much to be learned from these analyses as they point to imperative actors leading to the gas leak, which I have also used in my analysis. The current research all point out several factors in the reason for the leak, ranging from the malfunctioning tank, lack of safety procedures, and an ineffective MOC program. However, they do not connect all of the reasons together and point out the most dominant cause out of them all. This paper will not only provide both human and non-human actors for the accident, but will also use the actor-network theory framework to dismantle the pesticide actor-network and determine the actor that created the unstable network.

Conceptual Framework

My analysis of the Bhopal Incident draws on the science, technology, and society (STS) framework of actor-network theory (ANT), which allows me to distinguish the failure of the project while determining the major actor in the network of the pesticide plant. I will start by identifying actors, mainly organizational and conceptual actors within the Bhopal plant and connect these to similar themes, of which also connect back to a common actor.

ANT is an analytic device for deconstruction and critical analysis of the formation and function of complex sociotechnical systems. This theory analyzes the power dynamics among human and non-human actors that come together in a network designed to accomplish a particular goal (Cressman, 2019). An actor-network is composed of a series of heterogeneous elements that have been linked to one another for a certain period of time (Callon, 1987). It is simultaneously an actor whose activity is networking heterogeneous elements and a network that redefines what it is made of; it also simplifies heterogeneous elements into a cohesive network of human and non-human actors defined by their positions within the network itself (Callon, 1987). However, the actual development and progression of the network can be determined using Callon’s concept of translation (Callon, 1986).

Translation is the process that forms and maintains an actor-network. Callon outlines four phases of translation: problemization, interessement, enrolment, and mobilization (Callon, 1986). In problemization, a primary actor defines the problem and relevant actors necessary to solve it. They identify how to move the actors through the "obligatory passage point" (OPP) to establish the primary actors as "indispensable." In interessement, the primary actor attempts to recruit the other actors into the network and to align their interests with the problem which is originally defined by the primary actor. In enrolment, the primary actors assign roles to the other actors, and those assigned roles are performed within the network. Enrolment also demands that the other actors in the network actually accept and faithfully carry out their assigned roles as intended. Finally, in mobilization, the primary actors secure their role of representing the other actors in the network to mobilize them as a whole. Callon illustrates how an actor-network defined in such a way can fracture or fail if one or more of the actors refuses or is unable to perform the role assigned to it by the primary actor (Callon, 1986).

The network builder (one that recruits heterogeneous actors to accomplish a goal) in the Bhopal Incident is the UCIL pesticide plant in Bhopal, also known as the OPP. This builder recruited actors, like employees, safety measures, and equipment, to establish the safety of a stable treatment plant, or led to a lack thereof (Cressman). In the analysis that follows, I begin by identifying the network and major actors that make up that network, ranging from organizations to conceptual actors, that were responsible for the disaster. I will then determine the point of departure from the project goal to identify which common actor caused the unstable network to explain the responsibility for the gas leak that led to the loss of thousands of lives.

Analysis

Network Formation

The first step to constructing the UCIL pesticide plant actor-network is to define the heterogeneous actors that are present within the network. I have identified the human or social actors by determining the only groups of people that would be affected by this pesticide plant and are making decisions for it. These actors are (i) the local Indian government who make few overhead decisions for the plant ; (ii) the management of the plant itself that include the higher-up employees; and (iii) the laborers employed by the plant during the incident (Basha et al., 2009; Sharif, 2020; Stevens, 1984). Additionally, I have identified the non-human, or more specifically, conceptual actors by compiling the most pertinent decisions and occurrences that happened before and during the incident. These actors are (i) the safety measures within the workplace which affected equipment in the plant, and (ii) cost-cutting policies that affected many of the other actors in the network (Basha et al., 2009; Sharif, 2020). The company itself, UCIL, suggests that the company is the network builder, as mentioned above, and established this particular local network in this local plant. Within this local network are the various actors that are present in the pesticide plant's failure.

To determine how all of these human and non-human actors are associated with each other, it will be helpful to track the network's formation through the phases of translation from Callon.

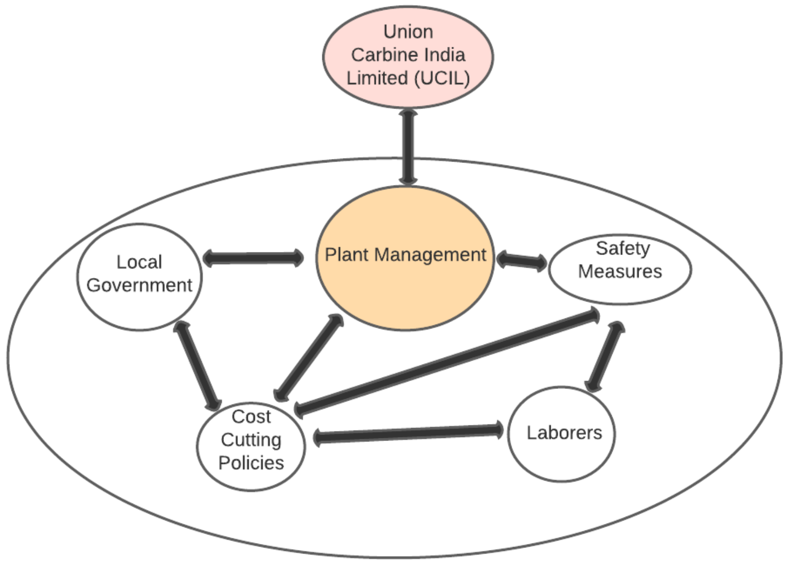

Figure 1. The Actor-Network of the UCIL Pesticide Plant

In Figure 1 above, I have laid out the actor-network for the plant with the relevant actors described previously. The arrows are connected to actors that are affected by one another during translation. During problematization, the first phase of translation, the plant management's goal is to produce MIC at a profit. In order to do so, the management must cut costs; the local government is a third party actor that is responsible for supplying that information to the management and fears losing an employer (National Research Council, 2012). The plant management also hired laborers in order to execute the tasks in the plant. From the figure above, all of the human actors all connect to cost-cutting which can also be seen as a major actor or factor in several decisions.

For the next step in interessement, the management can align the actors interests to their problem definition. They are able to easily hire many laborers quickly because they will work for less money and still do the work for their plant, though questionable. The local government and the management have the same goal - the plant's profitability - therefore, their interests are aligned already.

In enrolment, ideally, all of the human actors will assume and perform their roles within the network. Assuming this situation, the laborers must be in charge of operating the equipment, and thus must comply with the safety measures that come with it; this connection establishes a strong association between the laborers, equipment and safety measures. The management, and in turn the local government, both benefit from the cost-cutting since it serves the purpose of making profit on the MIC.

Network Instability

Since the aforementioned network was stable, the pesticide plant was able to function the way that it was outlined. However, in the enrolment step, the human roles derailed which in turn affected the non-human actors, and cannot proceed with the rest of the translation steps. The cost-cutting policies were a major obstacle that essentially led to the instability of the plant due to the negligence of the plant management. Below, I will deconstruct this actor-network, revealing the weak points of the plant and the connections of the actors themselves.

Local Government

The local Indian government (of Madhya Pradesh, India) is an actor that primarily had an overhead role that impacted the outcome of the decision-making process. Ultimately, the local Indian government did make decisions that affected the choices made, or lack thereof, by the plant management. UCIL claimed that it was pressured into manufacturing MIC by the

Government of India because of their policy of urging foreign companies to "indigenise" their production (Eckerman, 2004). While the plant was centered on making profit with MIC, it could be seen that this would not even be occurring if the local government did not order for the chemical to be produced in the first place. No action was taken by the government to ensure that hazardous conditions in the plant were corrected.

While the government is the reason for production in the first place, they also are involved in false claims. In 1982, The Employment Minister of Madhya Pradesh had announced that, "there is no cause for concern about the presence of the Carbide factory because the phosgene it produces is not a toxic gas" (Lapierre & Moro, 2001). Though after investigations to refute this claim, there was no answer from the government. Additionally, Union Carbide as well as Indian authorities purposely did not release information to cover-up what actually happened (Eckerman, 2004). This level of secrecy in the local government is a major reason that investigators cannot place blame on the incident as easily. Since UCIL was also involved in this, the close connection between the two is evident in their actions as they try to save their reputations together. While there are many people being silenced and documents are sealed away, this demonstrates guilt on the government. The lack of support to the survivors has, to a great extent, been dependent on politics; this disregard trickled down to the plant where all of the issues (the other actors in the network) were out-of-scope of concern for the government.

Safety Measures

The underinvestment of safety measures present at the Bhopal plant at the time of the incident was a major flaw in the plant culture. The lack of safety measures aided in the release of the MIC into the atmosphere. Dr. Srinivasan Varadarajan, the Indian Government's chief scientist, said his staff had been told by managers of the Bhopal plant that the refrigeration unit designed to chill the MIC, which he said was very small and had never worked satisfactorily, had been disconnected because the managers had concluded after discussions with American headquarters that the device was not necessary (Diamond, 1985). On the contrary, a spokesman at corporate headquarters in Danbury, Thomas Failla, said: "As far as we have been able to establish, the question of turning off the refrigeration unit was not discussed with anyone at Union Carbide Corporation" (Diamond, 1985). Already, there is miscommunication between the two establishments which have led to the lack of safety and consistency. Few, if any people, would have died the night of the lead had the unit been running because it would have slowed the chemical reaction that took place during the accident and increased the warning time. This demonstrates the refrigeration unit to be a major safety measure for the system that would have helped avoid disaster. Not only was the unit not in use due to messy miscommunication, there also was not a back-up unit present either. The safety measures are compromised even from before the incident. More investment and investigation should have been placed on what types of mitigating equipment should be in use should there be a large outburst. As these safety measures were compromised to the point where there almost was not any risk management involved in the plant, it is not surprising that an incident of this magnitude occurred. This actor (safety measures) was essentially unused, thus making the main function of the plant unstable in the network, independent of who allowed that to happen.

As previously stated, safety measures were underinvested, which allowed for further dangerous working environments to develop and ultimately to the spill of MIC. However, some might think that the safety measures were up to date and followed through. A Union Carbide commissioned analysis conducted by Arthur D. Little claims that a key intermediate valve would have had to be open for any issues to occur (Kalelkar & Little, 1988). The valve was “tagged” as closed, which means that it had been inspected, and that the plant management was thorough in its safety measures (Kalelkar & Little, 1988). But this view fails to consider that even if the specific route of the MIC hadn’t been exposed to the atmosphere the way that evidence claims, it does not negate the several warnings that the plant has received about a potential leak or disaster months and years prior. The plant management did not respond in any way to those warnings to repair and install additional safety measures. The safety measures were not put in place to deliver basic risk management practices and those operating them did not know enough to do so.

Laborers

Unraveling the unstable network, the laborers become unskilled laborers. Employee training and factory maintenance were cut and lower paid workers did not have the skill necessary to run the plant (Basha et al., 2009). Training levels, requirements for experience and education and maintenance levels had been sharply reduced, according to about a dozen plant employees. The staff at the methyl isocyanate plant, which had little automated equipment, was cut from 12 operators on a shift to 6 in 1983, according to several employees. Kamal K. Pareek, a chemical engineer who began working at the Bhopal plant in 1971 and was a senior project engineer during the building of the MIC facility said that the plant “cannot be run safely with six people” (Diamond, 1985). If a plant cannot be run with the amount of workers present, there is bound to be a flaw in the flow of the system. These six unskilled workers combined are not sufficient for a fully functioning plant. Since knowledgeable people are needed to operate the machinery, this reduces the chance of hiccups in the process, or quick fixes to problems. The presence of workers without this knowledge makes a clear way for mistakes to go by unnoticed, leading to further complications, like the gas leak.

Additionally, Dr. Varadarajan, the government scientist, said the Bhopal staff did not adequately measure the incidence in MIC (a routine test) or the possible effects of chloride ions, which are highly reactive in the presence of small amounts of water (Diamond, 1985). Here, their lack of knowledge affected the production and further reduced the effect of the safety measures that should have been in place. The actions of the laborers and misuse of equipment are tightly connected, as they are large components of the failing network. This itself demonstrates that the laborers that were hired did not work in the benefit of the plant, as far as running it smoothly. They were a hindrance due to their lack of skill and safety knowledge in the plant, leading to a severely unstable system, which was ultimately due to saving money.

Cost-Cutting Policies

Reducing cost was a major motivation for the plant that resulted in many unreliable systems. In Figure 1, cost-cutting policies are connected with every other actor in the plant network. Many safety systems were switched off to save money, like the aforementioned refrigeration system (Sharif, 2020). Employee training and factory maintenance were radically cut, and skilled employees were replaced with lower paid workers (Basha et al., 2009). Mr. Pareek, the former project engineer, stated that "top management decided that saving money was more important than safety" (Diamond, 1985). And, tying it to the local government, they were afraid of losing large employers if they spent money on aspects that were deemed unimportant in their terms (National Research Council, 2012). This demonstrates the local government still being in line with their goal of making profit, however, it makes the entire network unstable with just one choice. And naturally, since all of these actors were compromised to the point where they are not useful, maintenance practices became poor. Unfortunately, the goal of the plant was to make money; the only way for the plant to survive and do that was for the local government to pose several cost-cuts. The weak links of the network, safety measures and laborers, are all due to the cost-cutting policies put on the plant from the local government and plant management, which led to an insecure network.

Plant Management

All actors in the network essentially connect through the cost-cutting policies and to the plant management. The negligent actions of the higher-ups in this plant were mainly to blame for the leak. A corporate spokesman said that "responsibility for plant maintenance, hiring and training of employees, establishing levels of training and determining proper staffing levels rests with plant management" (Diamond, 1985). All of these aspects were neglected from the start. Though the local government did want to reduce cost, the plant management was responsible for how that was accomplished. It seemed as if the easiest solutions to cost-cutting were implemented instead of analyzing the possible negative effects of them throughout the network. And through those decisions, the safety of the workers and those around the plant were not considered as a part of the decisions. The almost non-existent supervision and poor training by the management were largely responsible for the eventual MIC leak.

Independent of the other actors, the plant management also made choices on its own that are to blame. This Operational Safety/Health Survey from a few months prior to the leak states that the team had two major concerns, one of which included the “potential for runaway reaction in unit storage tanks due to a combination of contamination possibilities and reduced surveillance during block operation" (Menon, 2017). This document additionally mentions that there have been instances of water contamination of the unit tanks in the past. However, these past instances have been handled with little issues and could have led to a sense of complacency, most likely on the management's part, and a lack of concern which could lead to an uncontrollable situation. With the official report that there was a risk in the production of MIC, there should have been more emphasis placed on the options to decrease this risk. Additionally, the Health Survey recommended a few measures that would aid in the continued use of the MIC storage tanks, though the plant did not follow through on any of them. Not implementing these recommendations are the exact opposite of what the report intended to do. The plant management chose to ignore this fair warning due to inaction on their part; an allegation of corporate negligence was clear in this case. Though this warning from the survey was not an actor in the network, it can be considered a rogue actor which brought light to the instability of the network before the other actors noticed. This report was a key piece of information that helped to determine the irresponsibility of the management and led to many actors falling out of place resulting in a deadly disaster.

Conclusion

In this paper, I have used the concept of ANT to determine the key actors to a stable UCIL pesticide plant which also resulted in its demise and deconstruction to identify the root cause of the MIC spill. After exploring how many of the actors were not able to perform their roles from the steps of translation, it is apparent that the gas leak is the result of an unstable and negligent plant management. Although equipment failures, lack of safety measures, and faults of unskilled workers increased the severity of the disaster, these failures and poor response are indicative of major flaws in the facility management in itself. This result will allow plants in the future to learn from mistakes and place a heavier emphasis on a strong, organized, and ethical management. Having an inherently strong safety culture sprung from the plant management is what will create a stable plant network. Through this mentality, it is possible for the company to make a profit while producing MIC, without risking the lives of thousands of people in and around the plant.

Word Count: 4165

References

Basha, O., Alajmy, J., & Newaz, T. (2009). *Bhopal gas Tragedy: A safety case study*. https://oaktrust.library.tamu.edu/bitstream/handle/1969.1/187848/CHEN%20455%20Bhopal%202009%20report.pdf?sequence=1&isAllowed=y#:~:text=On%20December%203%201984%2C%20in,many%20as%20300%2C000%20were%20injured1.

Benintendi, R. (2018). *Explosions*. https://www.sciencedirect.com/topics/chemical-engineering/thermal-explosion

Bhopal disaster | Causes, Effects, Facts, & History. (n.d.). Encyclopedia Britannica. Retrieved March 3, 2021, from https://www.britannica.com/event/Bhopal-disaster

Broughton, E. (2005). The Bhopal disaster and its aftermath: A review. *Environmental Health*, *4*, 6. https://doi.org/10.1186/1476-069X-4-6

Callon, M. (1986). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. *J. Law, Power, Action and Belief: A New Sociology of Knowledge? London, Routledge*, 196–223.

Callon, M. (1987). *Society in the Making: The Study of Technology as a Tool for Sociological Analysis*.

Cressman, D. (2019). *A Brief Overview of Actor-Network Theory: Punctualization, Heterogeneous Engineering & Translation*. ACT Lab/Centre for Policy Research on Science & Technology (CPROST) School of Communication, Simon Fraser University.

Diamond, S. (1985, January 28). The Bhopal Disaster: How it Happened. *The New York Times*, 1.

Eckerman, I. (2004). *The Bhopal Saga—Causes and Consequences of the World's Largest Industrial Disaster*.

Joseph, G., Kaszniak, M., & Long, L. (2005). Lessons after Bhopal: CSB a catalyst for change. *Journal of Loss Prevention in the Process Industries*. https://doi.org/10.1016/j.jlp.2005.07.009

Kalelkar, A., & Little, A. (1988). *Investigation of Large-Magnitude Incidents: Bhopal as a Case Study*. Cambridge, Massachussetts. https://www.bhopal.com/document/case-study.pdf

Lapierre, D., & Moro, J. (2001). *Five Past Midnight in Bhopal* (1st Indian Edition). New Dehli: Full Circle Publishing.

Menon, V. (2017, December 3). These documents show how India and Union Carbide colluded on the Bhopal Gas tragedy. *ThePrint*. https://theprint.in/theprint-primer/india-union-carbide-bhopal-gas-tragedy/19944/

METHYL ISOCYANATE. (n.d.). Retrieved March 10, 2021, from http://www.idph.state.il.us/Bioterrorism/factsheets/methyl_isocyanate.htm

National Research Council. (2012). *Bhopal and Chemical Process Safety | The Use and Storage of Methyl Isocyanate (MIC) at Bayer CropScience | The National Academies Press*. https://www.nap.edu/read/13385/chapter/5#32

Sharif, A. (2020). *Case study for Bhopal Gas Tragedy*. https://www.researchgate.net/publication/343601060_Case_study_for_Bhopal_Gas_Tragedy

Stevens, W. K. (1984, December 6). WORKERS AT SITE OF LEAK DESCRIBED AS UNSKILLED. *The New York Times*. https://www.nytimes.com/1984/12/06/world/workers-at-site-of-leak-described-as-unskilled.html

Taylor, A. (2014, December 2). *Bhopal: The World's Worst Industrial Disaster, 30 Years Later -*

The Atlantic.
https://www.theatlantic.com/photo/2014/12/bhopal-the-worlds-worst-industrial-disaster-30-years-later/100864/

What was Bhopal Gas Tragedy, Cause of Bhopal Gas Tragedy, Bhopal Gas Tragedy News | Business Standard. (n.d.). Retrieved March 10, 2021, from https://www.business-standard.com/about/what-is-bhopal-gas-tragedy