

Appendix E: Issues in Chemical Processing

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References used in this section:

Paul Shrivastava, *Managing Industrial Crises: Lessons of Bhopal* New Delhi: Vision Books, 1987
[an early sober analysis of the causes and how to avoid similar problems by a US-based academic born in Bhopal]

United States Government, Hazardous Substances Data Base

United States Government, Agency for Toxic Substances & Disease Registry

Additional readings:

Baldave Singh, "Bhopal's legacy: Indian producers feel cornered," *Chemical Week* 159/26 pp. 84-85 (2 July 1997) [Indian chemical firms' reactions to pressures that they sign on to privately-sponsored "Responsible Care" operating standards code of conduct.]

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Toxicity of Chemicals present in the Bhopal Plant

These entries from US government public databases notes reflect 2008 understanding of the toxicity, health effects, and best ways of treating persons exposed to the various chemicals involved in producing UCC's "Sevin" pesticide.

Physicians, nurses, and other emergency personnel in Bhopal had little information about either the composition of the gas cloud or the best ways of treating patients exposed to Methyl Isocyanate (MIC). A communication from a UCC staff physician at the West Virginia plant the day after the leak provided some information, including an instruction for treatment in the event cyanide poisoning was suspected. A long controversy about whether the suggested treatment should have been followed with all or some of the victims broke out, and to this day there is disagreement about whether cyanide poisoning occurred and whether this treatment would have helped the recovery of those exposed to the gas cloud.

Two links are given for most of the chemicals. The first link is to the Hazardous Substances Data Bank (HSDB). Type in the name of the chemical of interest and HSDB will give toxicity information and a chemical fact sheet with extensive information on the chemical's physical characteristics. The second links are from the Agency for Toxic Substances & Disease Registry (ATSDR), which show the chemical makeup and toxicity, and provide medical guidelines for treating persons who have been exposed to unhealthy levels of the chemical. ATSDR links go directly to the chemical of interest.

- 1.) MIC:
 HSDB: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.htm>
 ATSDR: <http://www.atsdr.cdc.gov/MHMI/mmq182.pdf>
- 2.) Phosgene:
 HSDB: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.htm>
 ATSDR: <http://www.atsdr.cdc.gov/MHMI/mmq176.pdf>
- 3.) Chlorine:
 HSDB: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.htm>
 ATSDR: <http://www.atsdr.cdc.gov/MHMI/mmq172.pdf>
- 4.) Alpha-Naphthol
 HSDB: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.htm>
 ATSDR: <http://www.atsdr.cdc.gov/toxprofiles/phs67.html> (*a Public Health Statement*)
- 5.) Methylamine
 HSDB: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.htm>
- 6.) Carbaryl (Sevin)
 HSDB: <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.htm>

This Chemical Fact Sheet for Carbaryl (Sevin) (the end-product insecticide produced at Bhopal) focuses mainly on hazards encountered in its ordinary use in diluted concentrations as a pesticide. The "Summary Science Statement" towards the bottom lists it as having "a moderate to low mammalian toxicity."
<http://pmep.cce.cornell.edu/profiles/insect-mite/cadusafos-cyromazine/carbaryl/insect-prof-carbaryl.html>

Fragmentary Notes on Chemical Processes for Producing SEVIN (Carbaryl Pesticide)

[MJ Peterson ver.2 27 Feb 2008]

ALTERNATIVE METHODS FOR PRODUCING SEVIN

Prior to 1968:

- a) phosgene + alpha-naphthol \rightarrow ??
- b) ?? + methylamine \rightarrow SEVIN + a toxic residue+ other waste products

This suggests some advantages to using the MIC process. Though MIC is very toxic, the overall reaction produces less undesirable residue and fewer waste products.

UCC process 1968:

- a) phosgene + methylamine \rightarrow methyl isocyanate
- b) methyl isocyanate + alpha-naphthol \rightarrow SEVIN

"The process (to make Sevin) uses a cost efficient one step-process using the highly toxic methyl isocyanate gas."

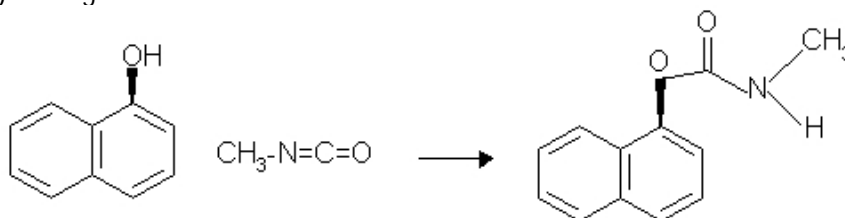


Image and quote from: http://www.chm.bris.ac.uk/webprojects2002/tan/bhopal_disaster.htm

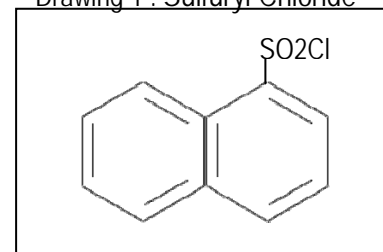
UCIL's original proposal for SEVIN production in Bhopal plant

1. UCIL will make alpha-naphthol by its own process of (see drawing 1)
 - a) Naphthelene + Chlorosulfonic acid \rightarrow Sulfuryl Chloride
 - b) Sulfuryl Chloride \rightarrow alpha-naphthol
2. Will produce phosgene by making carbon monoxide in plant then combining it with chlorine to form phosgene.
3. Then produce MIC using UCC process of
 - a) Methylamine + Phosgene \rightarrow Methylcarbamoyl chloride
 - b) Methylcarbamoyl chloride + ? \rightarrow Methyl Isocyanate

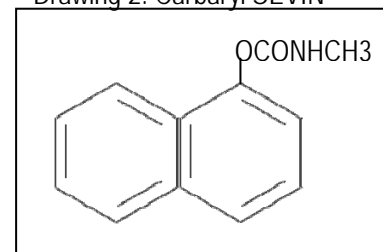
[a different account lists phosgene + monomethylamine \rightarrow MIC]

4. Then mix alpha-naphthol + MIC \rightarrow carbaryl SEVIN (drawing 2 or image above)

Drawing 1 : Sulfuryl Chloride



Drawing 2: Carbaryl SEVIN



In the 1960s and 1970s there were two ways to operate an MIC-based carbaryl production process:

a.) make MIC in advance, put it in bulk storage, draw from bulk storage as final production proceeds. This was Union Carbide's choice for West Virginia and Bhopal plants.

b.) make smaller batches ahead of production need and store in smaller tanks or drums. Used by Bayer A.G. in Germany, where plant never stored more than 10 tons of MIC and divided it among 4 separate storage tanks.

This should have been feasible for Bhopal plant, and some very anti-corporate sources even claim that UCIL proposed using a method more like this but that UCC preferred to base the Bhopal plant design on its West Virginia process.

By 1984 there was also

c.) use a closed cycle production system with newly-made MIC piped straight to mixing with alpha-naphthol. Mitsubishi was using this process in 1984 and DuPont was building it into a plant in Texas in early 1985.

This appears to be very capital-intensive and only workable if one has reliable power supply and very good computer control systems. Those features would make it unfeasible for the Bhopal plant. [Note by MJP: I would not be surprised to learn it was developed only after the Bhopal plant design was chosen in the mid-1970s.]

By 1984 Bayer A.G. was producing MIC with the less toxic component chemicals dimethylurea and diphenylcarbonate, but the resulting MIC was no less toxic. It is not clear whether this process was under patent. Having to license from Bayer would raise costs to UCC or UCIL and also weaken the impression of technological competence they needed to maintain vis-à-vis the Governments of India and Madhya Pradesh.

Data on Toxicity

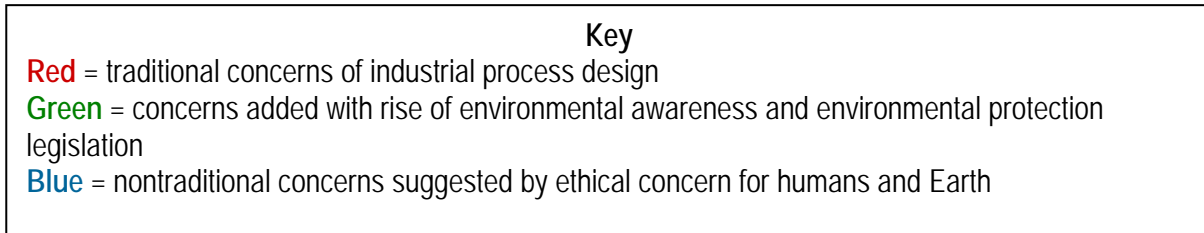
1976 Union Carbide Manual:

- chlorine, phosgene, monomethylamine and MIC all known to be deadly in sufficient concentrations.
- MIC listed as "relative, toxic, volatile, flammable."
- maximum safe workplace exposure is listed as 0.2 parts per million over an 8 hour period

Current Chemical Fact Sheet for Carbaryl (Sevin) the end-product insecticide produced at Bhopal: <http://pmep.cce.cornell.edu/profiles/insect-mite/cadusafos-cyromazine/carbaryl/insect-prof-carbaryl.html>

Types of Hazard in Manufacture and Use of Industrial Products

Classification of Production System, Production Environment, and Post-Production Effects inspired by Paul Srivastava, *Managing Industrial Crises: Lessons of Bhopal* New Delhi: Vision Books, 1987. Pre-Production Effects and color scheme by MJ Peterson, 17 Jan 2008.



Pre-Production Effects

(potential impacts of extracting and transporting raw materials, processed materials, or assembled components used as inputs to production facility)



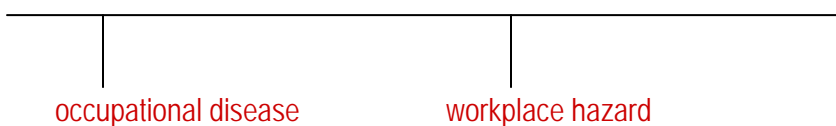
Production System

(potential impacts of using the machines and other equipment included in basic design of the production process to be used)



Production Environment

(potential impacts of production activity in the production facility)



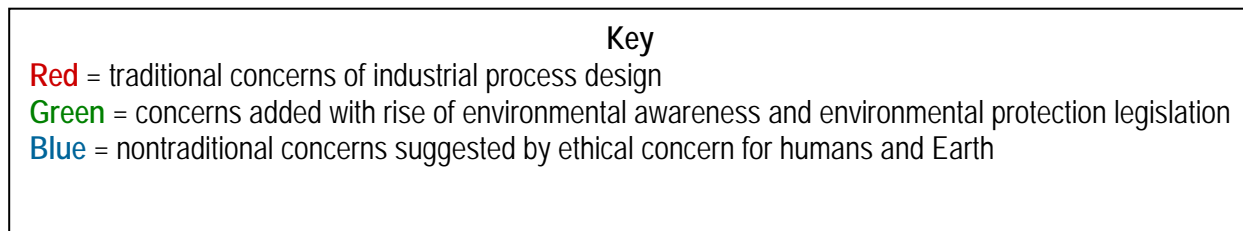
Post-Production Effects

(potential impacts of emissions and/or wastes resulting from production activity)

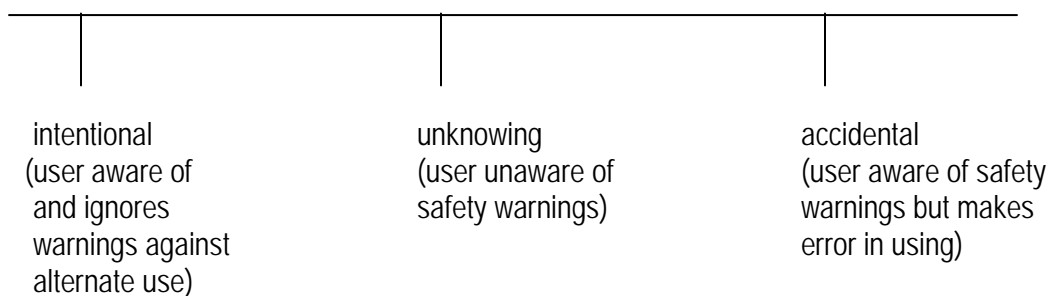


Types of Hazard in Product Use/Consumption

built out from Paul Shrivastava, *Managing Industrial Crises: Lessons of Bhopal* New Delhi: Vision Books, 1987. Color scheme by MJ Peterson, 17 Jan 2008.



Product Misuse



Product Defect



Product Sabotage



<end>