

B. HYDROLYSIS OF TCB

5. Recognition of TCDD in NaTCP: A Chronology

e. Chronology of the Recognition of TCDD

- 1957 Steps taken in 1957 to reduce worker exposure included installation of a Fletcher centrifuge,³⁸ reducing fume problems by making a more dilute NaTCP solution prior to the condensation step,⁴⁴ and installing a centrifuge plow.⁴⁶
- 4/17/59 Monsanto personnel are not aware of any publication of the BASF runaway reaction.²⁶⁶ Reference is made to a Thompson-Hayward accident using the ethylene glycol low-pressure process.
- 6/16/59 E. P. Wheeler acknowledges receipt of a translation of the Kimmig and Schulz article,²⁶⁷ regrets that Monsanto Research and Mellon and Kettering did not discover the TCDD causative agent.
- 3/60 Another industrial hygiene survey was done at Nitro.⁵⁷
- 3/16/60 L. C. Weger describes results of Diamond Alkali runaway hydrolysis on 2/20/60.²⁶⁸ After 11 days no new cases of chloracne had occurred; personnel entering the area took protective precautions. Process safety information, specifically TCB feed over a period of time, had been given Diamond Alkali by Monsanto the year before, but they had not taken the time to install such a system. Weger suggests points for safety review at Nitro.
- 7/22/60 Dust collector installed at packaging station to reduce dust exposure.⁶⁵
- 9/60 Meeting of Monsanto personnel with Dr. Suskind (Kettering Labs) and Dr. H. Oettel (BASF) reviewed the investigations of the two companies' runaway reactions.²⁵⁵ BASF's bromsulphophthalein retention test in rabbits as quality control for TCP is described more fully. Dr. Oettel stated Boehringer (in Germany) had experienced a decomposition in NaTCP production and had had many cases of chloracne for years; their TCP failed BASF's bromsulphophthalein test. Oettel and Suskind agreed that the rabbit ear test is unrealistic and non-reproducible.

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- 9/8/60 L. C. Weger discussion with Diamond Alkali indicates their work on a chloracne-inducts chlorinated diphenyl ethers.²⁶⁹
- 1961 Another article, using rabbit ear and ingestion tests, relates TCDD to chloracne and liver damage; continuation of the 1957 Kimmig and Schulz article.²⁷⁰
- 8/63 New integrated facility for NaTCP and 2,4,5-T production started up.⁸⁹ A number of provisions for less worker exposure were incorporated.
- 10/22/64 Rabbit ear tests by Younger Laboratories (for Monsanto) showed by-product 2-methoxy-4,5-dichloro-phenol and 4-methoxy-2,5-dichlorophenol (structures in eq. 8, Section VI) to be non-chloracnegenic, and TCP distillation residue was again confirmed as chloracnegenic.²⁷¹
- 2/24/65 In Dr. R. E. Kelly conversation with V. K. Rowe of Dow, Dow has 20 new cases of chloracne.¹¹⁸ They found 3-10 ppm TCDD in five shipments of 2,4,5-T from Monsanto and were having a management meeting to decide whether to use them. They are convinced TCDD is a major chloracne impurity. They are confident of the rabbit ear test. Dow wants a "crash" meeting with other producers to reach a specification level for TCDD in 2,4,5-T and related products. Dow has had chloracne complaints from customers. Dow has heard that the U.S. Public Health Service is investigating chloracne complaints of Dow customers. Monsanto is unaware of any customer complaints of chloracne, but will investigate.
- 3/3/65 No severe chloracne cases were noted at Nitro 1960-1964; only four cases since new plant startup in mid-1963. No cases of chloracne found at J. F. Queeny Plant in ester manufacture.²⁷²
- 3/23/65 A TCDD sample and hints on analytical procedure were received from Dow by Monsanto Agricultural Division Research, and GLC method development was started.¹²⁰

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- 3/25/65 First determination of TCDD in Na 2,4,5-T filter cake was about 10 ppm.²²⁵
- 4/1/65 TCDD in Na 2,4,5-T filter cake was not altered by NaOCl treatment.²²⁵
- 4/7/65 The TCDD sample received from Dow was analyzed for C, H, and Cl by Galbraith Laboratories.²²⁵
- Comment: Analyses do not reveal highest purity TCDD.
- 4/15/65 Filtration of NaTCP showed an 88% reduction in TCDD content.¹²⁰ A Dow 2,4,5-T sample had no detectable TCDD in it.¹²⁰
- 6/22/65 This is the date on the Dow Analytical Method (GLC) for TCDD in 2,4,5-T.²⁷³ It involves extraction, concentration, and GLC determination.
- 7/13/65 Distillation of TCP (from plant NaTCP) containing 15 ppm TCDD gave distillate with no detectable TCDD and residue with 400 ppm TCDD.^{225,226}
- 9/14/65 Research data showed TCDD in NaTCP at Nitro plant had averaged 5-12 ppm over the period 1953-1964.¹²⁵ Some much higher values (to 60 ppm) in April 1965 were unexplained. Four autoclave batches were sampled and analyzed during the hold period. Disappearance of TCB, decrease in TCA and increase in TCP and TCDD contents were plotted. It is concluded that a detailed laboratory study of the autoclave reaction could lead to an appreciable diminution of TCDD formation, and such a study is in the planning stage.
- 10/65 Dow was contacted concerning removal of TCDD and its disposal, but any information obtained was not in the available documentation.^{274,275}
- 8/11/66 A number of projects for reduction of dust and fumes in the Nitro plant were undertaken.¹⁴⁰

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- 12/1/66 Dr. R. E. Kelly states that chloracne, while mild, is a continuing problem at Nitro and has occurred at W. G. Krummrich and Luling ester operations.²⁷⁶ A new industrial hygienist is being hired for Nitro. Although improved equipment and hygiene practices help, the eventual solution must be avoiding manufacture of the chloracnegen.
- 1967 Nitro laboratories were set up for routine analyses of TCDD in 2,4,5-T product, will try to analyze NaTCP also.²⁷⁷ Research, Industrial Hygiene, and Manufacturing debate further approaches to chloracne problem.^{278, 279, 280} Dust and fume elimination projects were completed.^{147, 239}
- 2/13/68 Work was started on Research autoclave study to reduce TCDD.^{282, 283}
- 6/28/68 Dr. R. E. Kelly urges vigorous pace on TCDD reduction program,⁸⁵ asks if it is true Dow and Hercules have no new cases of chloracne, and if an attempt should be made to purchase their knowhow.
- 10/68 Nitro Research process improvement plan calls for studies on TCDD removal by NaTCP filtration and flash distillation in addition to ongoing autoclave studies.^{173, 284}
- 1968 Installation of equipment for charging methanol and NaOH under pressure to their autoclave reduced cycle time by two hours and halved the TCDD content.^{159, 160}
- 1/69 Results of Agricultural Research autoclave study published.^{155, 285} Recommended process called for essentially doubling the methanol: TCB molar ratio and some increase in NaOH:TCB ratio. Predicted TCDD in 2,4,5-T would be consistently below 2 ppm. Immediate testing in the plant autoclave was undertaken.^{286, 174, 233} Reduction of TCDD in the NaTCP from 10.5 ppm to 3 ppm was shown in February.²³³

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2/10/69 Preliminary report from Bionetics Research Laboratories on teratology studies on 2,4,5-T commissioned by the National Institutes of Health²⁸⁹ was received by Monsanto. The study showed teratogenic effects and liver damage in rats and mice.

Comment: Sample used apparently contained 27 ppm TCDD (see below).

4/8/69 Dr. R. E. Kelly knows of no tests (animal or human) which would prove that current 2,4,5-T with its low level of TCDD was not chloracnegenic.²⁸⁷ No letup in preventive measures should be permitted.

4/69 Agricultural Division Research monthly summary states TCDD content in NaTCP now 1-3 ppm, and TCDD in 2,4,5-T not detectable.²⁸⁸

Comment: Lower detection limit of analytical method in use at the time was probably about 1 ppm.

10/13/69 Department of Defense was not given toxicity data in Fort Detrick's recommendations to use Orange.²⁹⁰

12/69 Process Amendment authorizes test of shorter TCB addition time and hold time (total autoclave cycle time).^{183, 184} These could have further reduced TCDD formation. No documentation shows that tests were made.

2/12/70 Dow studies using 2,4,5-T with less than 1 ppm TCDD are showing no teratogenic effect.¹⁸⁵

2/19/70 Meeting was held with Monsanto and Hooker represented.²⁹¹ Dow had analyzed 2,4,5-T used in Bionetics study, found 27 ppm, TCDD. It was agreed that a specification for TCDD in 2,4,5-T needs to be set with Federal agencies. GLC methods now in use by 2,4,5-T manufacturers (flame ionization detector) are accurate to about 1 ppm TCDD. A new method (FDA) involving an electron capture detector, much more sensitive, is being investigated.

2/24/70 New Monsanto specification was issued for 2,4,5-T including 1 ppm maximum TCDD content.²⁹²

VII. BASIC CHEMISTRY OF 2,4,5-T PRODUCTION - Page 30

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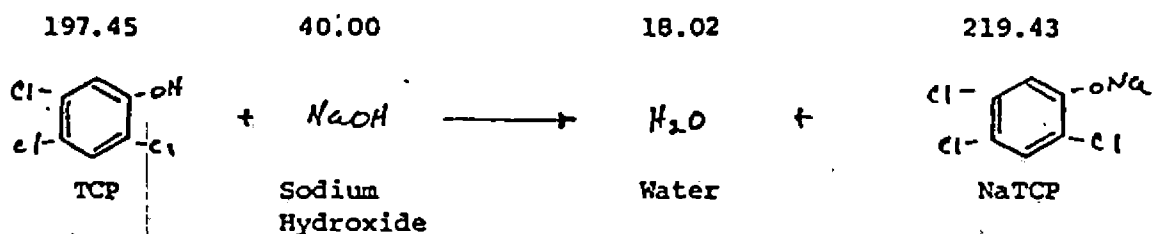
- 2/24/70 FDA and NIH are conducting new teratology studies with commercial 2,4,5-T containing less than 1 ppm TCDD.²⁹³ V. K. Rowe of Dow stated rabbit ear tests showed 2,4,5-T used in Bionetics study (27 ppm TCDD) was chloracnegenic, whereas 2,4,5-T with less than 1 ppm TCDD was not.
- 1/29/71 Reduction of TCDD in a 2,4,5-T ester (specifically the isooctyl ester) from 1-3 ppm to 0.35 ppm by treatment with a specific activated carbon was shown.²⁹⁴ It was successfully applied to 650,000 lbs. of material in stock.²⁹⁵

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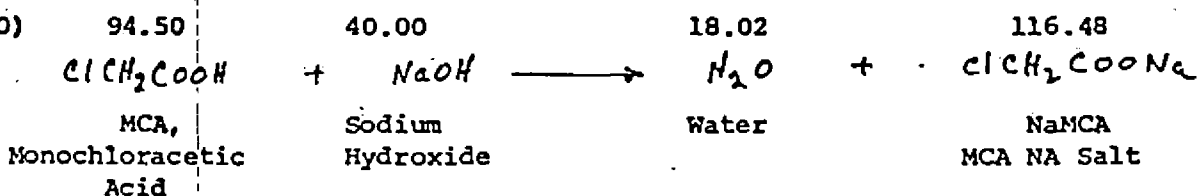
C. CONDENSATION REACTION

2,4,5-T was made by reacting NaTCP with MCA and acidifying to precipitate the solid 2,4,5-T. TCP was converted to Na TCP by equation 9. MCA was converted to NaMCA by reaction with NaOH (eq. 10) or with sodium carbonate (eq. 11). Solutions of the two salts were then reacted to give Na 2,4,5-T (eq. 12). A side reaction (eq. 13) was hydrolysis of some of the NaMCA to sodium glycolate.

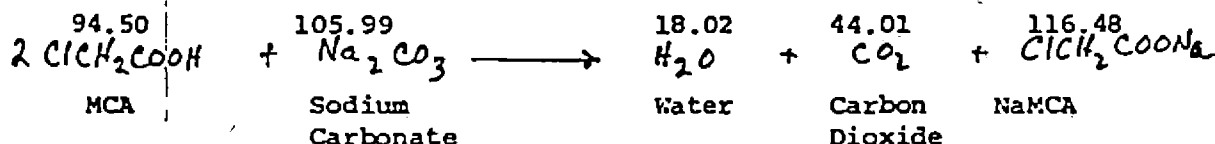
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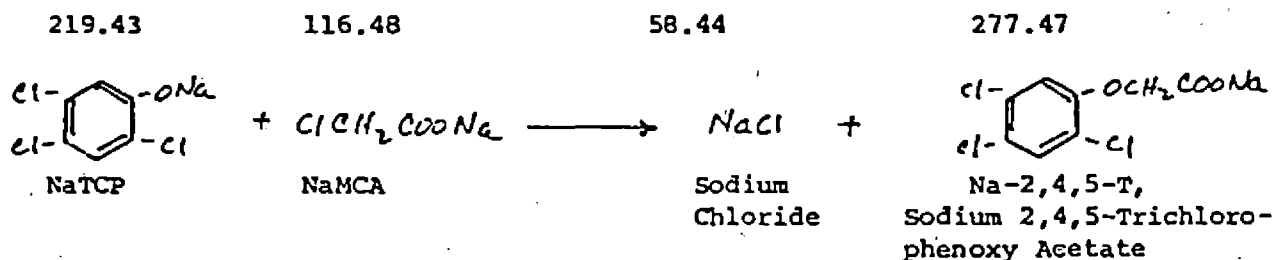
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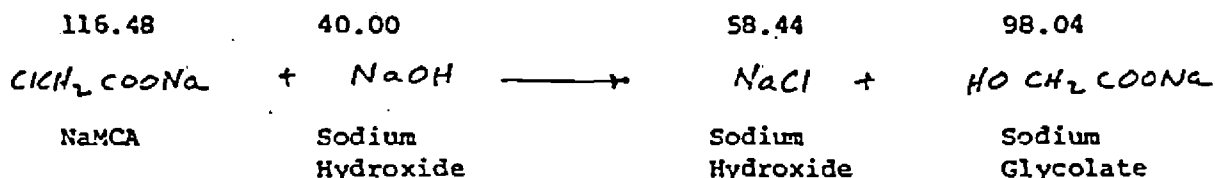
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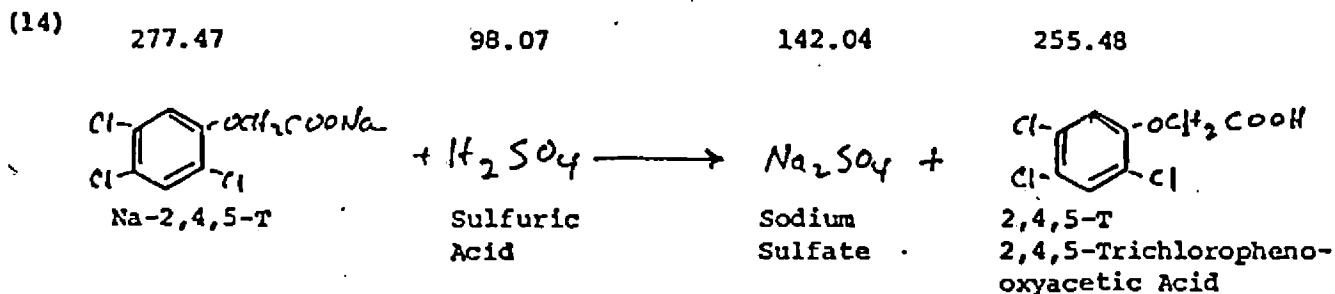


(13) Side Reaction:



D. ACIDIFICATION OF Na 2,4,5-T

Na 2,4,5-T was acidified (eq. 14) with sulfuric (or hydrochloric) acid to precipitate 2,4,5-T, which was filtered out and dried.

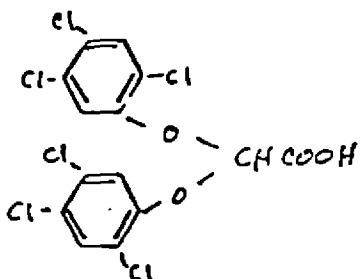


(15) Other Possible Impurities:

(a) In MCA raw material:



(b) In 2,4,5-T:



" bis-T "
bis-(2,4,5-Trichlorophenoxy)-Acetic Acid

E. RECOVERY OF TCP

Unreacted TCP in the filtrate after separating out the 2,4,5-T was precipitated by reaction with additional sulfuric acid (eq. 6) and the recovered TCP was recycled to the process.

