Nature Vol. 263 October 14 1976

Seveso: the aftermath

Alastair Hay reports on developments since a chemical explosion rocked this northern Italian town

THREE months have elapsed since the now notorious Séveso accident of July 10. It occurred when a reactor producing trichlorophenol at the ICMESA chemical plant—owned by Givaudan, a Hoffman-La Roche subsidiary—became overheated: the rapid pressure increase that followed led to the discharge of its contents through a safety valve directly into the atmosphere. Scientists have since been engaged in decontamination work in the area, which was affected by the fallout of TCDD (2,3,7,8-tetrachlorodibenzo-para-dioxin) as the disastrous consequence of that discharge. A considerable amount of disturbing information has now come to light concerning both the operation of the ICMESA plant, and the decontamination procedures adopted.

Givaudan began to produce trichlorophenol at the ICMESA plant only in 1975. The monthly output of the plant was 5 tons but, in producing this quantity of trichlorophenol, the reaction also produced 1.2 kg of dioxin. This, according to an Italian trade union document, is the quantity which ICMESA was required to dispose of every month. It represents a high level of dioxin formation, of the order of 200 p.p.m.

According to a report in *The Times* earlier this week, however, Dr Donald Lee, the British expert now investigating the accident, is thought to have told the Italian authorities that up to 130 kg of dioxin could in fact have been produced in the explosion. His recommendations are said to include the suggestions that residents should have medical tests for the rest of their lives, that the contaminated area should be monitored for decades, that this and a buffer area should be sealed off to all but authorised personnel, and that decontamination procedures should involve the creation of forests and dismantling of buildings rather than the shifting of earth and the washing of buildings.

Although a senior Roche executive says, according to the Italian weekly *L'Espresso*, that the company was producing TCDD deliberately for military purposes, Givaudan has denied the allegation. But Professor Fritz Mori, designer of the trichlorophenol reactor at ICMESA, has referred to the cause of the dioxin formation through a sudden rise in temperature within the reactor and gone on record as saying it would be impossible "unless the reactor was being used to produce substances other than the trichlorophenol it was designed to produce". The design of the reactor involved in the accident has come in for severe criticism, for incorporating safety features inadequate for the production of chlorinated phenols.

Information possibly vital to the resolution of the problems of plant operation, design and safety, however, is still not available to the Italian authorities. As for the estimate that the residents of Séveso and its surrounding area will not be allowed to return to their homes for at least a year, this is regarded as optimistic by many scientists. Although vegetation from the less contaminated zone is now being incinerated, no specific plan for removing dioxin from the soil has yet been agreed. Originally, topsoil from the total area contaminated was to have been cleared and processed to remove dioxin. However, some recent tests have revealed dioxin at a depth of 25 cm. The original proposition, which relied on TCDD being close to the surface, is now considered to be too difficult an undertaking, and operations will be confined to removing dioxin from the 30–40 hectare zone most severely contaminated.

Antidote claimed

Givaudan claims to have developed an antidote which will destroy the dioxin, consisting of an olive oil–water emulsion and cyclohexanone. In principle, the dioxin is detoxified by rupture of the linked ring system and the removal of the chlorine atoms by the unsaturated bonds of polyunsaturated fatty acids present in the olive oil. Ultraviolet light absorbed by the cyclohexanone initiates the reaction sequence. However, the Italian authorities, as well as American and British scientists, are sceptical about the success of the Givaudan claim. The Italians and Americans maintain that there is no effective antidote for TCDD. And Professor Derek Bryce-Smith of Reading University says sunlight does not contain a high proportion of ultraviolet in the wavelength range where cyclohexanone absorbs it. Although the photochemical reaction may take place in the laboratory, there is, he says, a real danger of moving dioxin so that it is harder to get to.

TCDD is virtually insoluble in water, and for this reason is not translocated rapidly in soil. Placing a dioxin solvent on the soil—TCDD is partially soluble in organic solvents—could obviously assist in moving the dioxin to greater depths. Another complication is the fact that cyclohexanone is itself a dangerous chemical: its flash point, only 63 °C, is well below its boiling point of 155.6 °C; in terms of human toxicity, it is considered a weak narcotic, and it also irritates skin and mucous membranes; the lethal dose for mice is 8,000 p.p.m. in air.

Sorry, for copyright reasons some images on this page may not be available online

Keystone

Four-year-old Séveso victim

The reports causing most worry, though, are those concerning the results of the blood tests carried out on the ten thousand residents of the Séveso area. Information not yet released by the Italian health officials confirms that 5–10% of the people examined are showing reduced white cell blood counts. Although it is only three months since dioxin was released, and a reduction in blood lymphocyte count is a secondary effect of damage to the immune response tissue—which dioxin is known to affect—these results are causing great concern. The situation is expected to worsen, and more residents may show adverse clinical symptoms; persons already affected could record a further reduction in their white cell count. But some scientists who have recently returned to the UK after visiting Italy feel that symptoms of dioxin poisoning are less serious than was originally feared.

Given the known teratogenic properties of dioxin, 150 women from the Séveso area who were in the first trimester of pregnancy at the time of the explosion have applied for an abortion. By the end of September, 25 women had received government authorisation for the operation, in the face of great opposition from the Catholic Church. Authorisation for another 125 women is also likely.

Health officials have examined a total of 730 pregnant women formerly resident in the contaminated area. The difficulties in securing legal abortions have added considerable impetus to the campaign for abortion law reform; the Italian parliament is to consider several bills advocating changes.

In view of the known toxicity of TCDD and the knowledge that it is a constant by-product of the trichlorophenol manufacturing process, many scientists are now beginning to question the need for the continuation of trichlorophenol production. One of the two

The possible alternatives

THE available alternatives to 2,4,5-T are 'Amcide', 'Glyphosate' and 'Krenite'; all three are effective brushwood killers. Amcide has been available in the UK since the early 1960s; Glyphosate is a more recent addition, and Krenite is at present only on sale in the US and West Germany.

These alternatives, when compared with 2,4,5-T, have some definite advantages. Amcide, made by Nissan in Japan, has an LD_{50} value for rats of 3,900 mg kg^{-1}; Glyphosate, made by Monsanto, has an LD_{50} value of 4,900 mg kg^{-1}. These toxicity ratings are well below that for 2,4,5-T (LD_{50} value 300 mg kg^{-1}). Krenite, made by Dupont, has an LD_{50} value of 24,000 mg kg^{-1}, a toxicity rating one eightieth of that for 2,4,5-T.

The reaction to produce Amcide presents none of the potential hazards associated with trichlorophenol manufacture in terms of toxic by-products. Information has not been made available for Glyphosate or Krenite production. However, in the case of Krenite the US Environmental Protection Agency (EPA) considers its manufacture to conform to accepted safety standards, and in view of its comparatively low toxicity has declared it as safe for use even on land adjacent to domestic water supply reservoirs and streams.

The disadvantages associated with the three alternatives are primarily those of cost. Amcide and Glyphosate are more expensive than 2,4,5-T when the concentrations of herbicide necessary to effect the same plant kill ratio are considered; Glyphosate is nearly five times as costly. Some potential buyers of Krenite consider that it, too, may be expensive when it is introduced on the UK market. The only other problem of any consequence relates to Amcide. In contrast to 2,4,5-T which is absorbed through leaves following spraying, Amcide must be applied to cut surfaces on plants. Its method of application is therefore considerably more labour intensive.

Hexachlorophene, the other major product derived from trichlorophenol, is a general poison effective in the control of gram-positive bacteria. In the cosmetics industry hexachlorophene is used as a preservative. For medical purposes hexachlorophene is used in the control of staphylococcal organisms. The bactericide has four main uses: treatment of acne and impetigo, cleansing of intact skin around burns or wounds, pre-surgical washing, and cleansing of new-born infants, particularly the umbilical cord.

Its use, however, has been much reduced, and the industry is reported as being able to dispense with it altogether. Chlorhexidine—a bactericide now cleared for sale in the US—is used surgically in the UK as a skin cleanser, wound steriliser and for pre-surgical washing. On the question of the cleansing of the newly-born infant, however, there is a difference of opinion as to which of the two bactericides is the most effective.

Maternity clinics and nurseries are particularly open to bacterial cross-infection by the staphylococccal organisms. One of the most common is *S. aureus*. In the 1940s this organism was responsible for frequent epidemics in nurseries, with a consequent increase in infant mortality. When hexachlorophene was first marketed by Givaudan in the late 1940s it proved to be effective both in the routine containment of *S. aureus* and in controlling the organism in the case of an epidemic. As a result of its efficiency, hexachlorophene rapidly replaced the bactericide 'Triple Dye' in use at that time, to become the most widely used antibacterial agent in nurseries.

Two events in 1971 and 1972, however, caused users to reconsider their judgment. The first was a report by the EPA showing hexachlorophene to cause oedema and hindlimb paralysis in experiments on mice. The second was the death in France of 35 infants following the use of talcum powder containing 6% hexachlorophene. The neurological damage which led to the death of the children was caused by a twenty-fold increase of hexachlorophene concentration in the talc, the result of a manufacturing error.

Many maternity units in the UK have since reduced the amount of hexachlorophene used for infant washes. Currently less than half use hexachlorophene at all. Others rely on alcohol, used either alone or with chlorhexidine. Consultants at one cross-infection laboratory now recommend nurseries to avoid the use of hexachlorophene altogether for routine washes. The reasoning behind this recommendation lies in the evolution of *S. aureus* itself, which has evolved through several forms since the 1940s and is now active as a complex of *S. aureus*.

The present generation of the bacterium is not causing serious epidemics in British hospitals which are fatal to children. Indeed the risk associated with hexachlorophene use is considered to present a greater threat than that represented by the staphyloccus itself. A further consideration is the fact that many British maternity units use a concentration of hexachlorophene to control *S. aureus* which is too low to kill the bacterium.

In the routine control of *S. aureus* chlorhexidine is as effective as hexachlorophene, and has the added advantage of an LD_{50} value ten times higher. Chlorhexidine is also reported to be just as efficient in controlling local epidemics of the present milder strain of the bacterium. It has not been tested, however, with more lethal strains of the staphylococcus, whereas hexachlorophene has been shown to control dangerous epidemics of *S. aureus* in the past. Some bacteriologists anticipate that chlorhexidine will prove to be equally effective, but are reluctant to recommend it unequivocally as an alternative until this has been demonstrated conclusively.

Although the principal purpose behind trichlorophenol production is the synthesis of 2,4,5-T and hexachlorophene, the chlorinated phenol is still used to some extent as a slime control agent in the paper-making industry. It has never been as popular as pentachlorophenol, used for the same purpose, and what use it has had has been much reduced, due mainly to the criticisms of the unrestricted industrial use of polychlorinated biphenyls (PCBs) such as DDT, advanced by the environmental lobby.

In common with many industries which discharge effluent directly into rivers, the paper manufacturers have been particularly sensitive to the charge that their plant operating procedures are damaging to the environment. Because of the known risks associated with extensive PCB use, paper manufacturers in the UK have considerably reduced their use of all chlorinated phenol derivatives. Agents now preferred for the prevention of fungal growth include methylene *bis* thiocyanate together with some organobromine and organosulphur products.

products derived from trichlorophenol —the herbicide 2,4,5-trichlorophenoxyacetic, 2,4,5-T (the other is the bactericide hexachlorophene) — has many formulations which contain the dioxin contaminant. In view of this the Norwegian authorities banned the use of the herbicide altogether in 1973. The US Environmental Protection Agency (EPA) regards 2,4,5-T as a product which may be too hazardous to man and the environment to permit continued use.

In the UK, however, the Ministry of Agriculture, Fisheries and Food's 1976 "List of Approved Products for Farmers and Growers" contains five formulations of 2,4,5-T alone, and eight of 2,4,5-T in combination with 2,4-D (2,4-dichlorophenoxyacetic acid). These products are sold as bramble, brushwood and nettle killers. A new formulation of 2,4,5-T, 'Silvapron T', produced by British Petroleum, is currently on trial in Britain. The herbicide is dispersed in an oil-based mixture which avoids some of the problems of volatilisation encountered with the traditional water-based mixtures. This BP formulation is restricted to forest areas.

The cost mounts

Neither product unique

But neither 2,4,5-T nor hexachlorophene is unique. Alternative herbicides and an equally effective bactericide are available (see box). Because of this, many scientists now question the desirability of using a reaction as dangerous as that involved in synthesising trichlorophenol. They point out that, with one exception, every plant producing trichlorophenol has had a serious accident involving release of dioxin, and injury to workers and the general public. The list of accidents begins with Monsanto (US) in 1949; then comes Badische Anilin und Soda Fabrik AG (West Germany) in 1953, Philips Duphar (Holland) in 1963, Dow Chemical Company (US) in the early 1960s, Coalite and Chemical Products Ltd (UK) in 1968, and finally, Givaudan-ICMESA (Italy) in 1976. Bayer of Leberkusen (West Germany) is the sole apparent exception.

But it is not only scientists who are concerned about the operation of the trichlorophenol process. The Italian authorities have invited Givaudan to build a new chemical plant near Séveso, with the provisos that it utilises reaction processes known to be safe and that trichlorophenol is not produced. Two other manufacturers of trichlorophenol are equally concerned; the Coalite and Bayer plants have both temporarily ceased operation. Additional safety features are to be introduced at Coalite as a result of recommendations by the UK Health and Safety Executive, but forty-nine of the fifty workers have refused to work there under any circumstances.

The trichlorophenol manufacturing process is only one of the potentially hazardous operations which will now come under closer scrutiny as a result of the devastation at Séveso. There are few processes which can have the unique record of an almost one-to-one ratio of accidents to production sites. However, there may be some where the value to society of the products manufactured is not sufficient to justify continued operation. The disaster in Italy will provide the backcloth for the debate which could help to resolve these issues.

● Yet another release of a dangerous chemical occurred in Italy on 26 September. This time between 10 and 30 tonnes (according to different sources) of arsenious oxide "escaped" from the ANIC chemical plant—a subsidiary of the Italian state fuel concern ENI—near Manfredonia on the Adriatic coast.

Over fifty people including two infants have been hospitalised with suspected arsenic poisoning (LD_{50} for rats is 138 mg kg^{-1}). The ANIC plant management only admitted the risk to local residents when the results of tests carried out by health officials confirmed a serious pollution hazard. The mayor of a town in the affected area appealed to the Italian government for assistance; no response came for several days. ANIC officials now say all but 1 km^2 of the area has been rendered harmless.

This has been done by spraying with calcium chloride and ferric sulphate solutions. When arsenious oxide is in a soluble form these two additives will form complexes of calcium pyroarsenite and ferric enneaoxyarsenite respectively. Both complexes are considerably less soluble than the oxide and would thus reduce the amount of arsenic leaching into the water system and spreading far beyond the present area of pollution.

Poppetoto

Sorry, for copyright reasons some images on this page may not be available online

Sorry, for copyright reasons some images on this page may not be available online

Keystone

Feeding cows to be destroyed

Inspecting ANIC plant