Dr. S. Varadarajan, Director of CSIR - Interim Report after Bhopal disaster to the Indian Government

On Measures Taken at Bhopal

9th January 1985

COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

MEASURES TAKEN AT BHOPAL

Introduction

The Director-General, Council of Scientific & Industrial Research, Dr. S. Varadarajan, had planned to visit the Regional Research Laboratory of CSIR at Bhopal on 5th December, 1984. He was asked by the Cabinet Secretary on 4th December to coordinate all scientific efforts at Bhopal in relation to situation following the leakage of toxic material on the early morning of Monday, the 3rd December, 1984.

Dr. Varadarajan and other scientists and technologists and officials from CSIR and other organisations were in Bhopal from 5th to 20th December. A list of those who were present in Bhopal at various times is given in Annexure I.

General Conditions in Bhopal

It was found that there were very considerable tragic consequences as a result of the leakage of toxic material and several deaths had been reported and many deaths continued to occur on 5th. There were also considerable worry about the safety of air and water. The factory work had been stopped and police had been posted. A case had been registered by the CBI against five officers of factory and who were also under arrest within the factory premises. Most of the factory workers were also not available. A large contingent of police occupied the factory premises. All the shops had been closed. Transport facilities were not readily available. Telecommunication facilities were extremely poor and had been disrupted. A large number of animals had also died. Disposal of the dead as well as the disposal of animal carcasses presented serious problems. With still many doubts about the toxic nature of water, air and foodstuffs, there was considerable fear among the public. A large numbers affected outside of Bhopal were being brought to hospitals. The medical services were highly strained to meet this situation.

There were over 300 correspondents, 50 of whom were foreigners or representing foreign agencies and television teams were also present. They were also entering factory and hospitals freely.

Prior to his departure from Delhi, on 4th Dec. Dr. Varadarajan arranged for scientific teams from National Environmental Engineering Research Institute (NEERI), Nagpur, Industrial Toxicology Research Centre (ITRC), Lucknow the National Institute of Occupational Health (NIOH) of ICMR, Ahmedabad, to arrive in Bhopal on 5th December, 1984. A Central Coordinating Cell was set up on 5th atRRL, Bhopal headed by Professor P.K. Rohtagi Director of the Laboratory. Appropriate analytical and testing facilities and transport were arranged for scientists who arrived. Accommodation was also arranged for the large number of scientists and technologists arriving in Bhopal.

Following a meeting with the Chief Minister, Mr. Arjun Singh, State Government officials and Mr. Vasant Sathe, Minister for Chemicals & Fertilisers on the 5th morning, Dr. Varadarajan accompanied Mr. Sathe to the factory and had discussions with the Factory Manager and also accompanied Mr. Sathe to inpect the location of the MIC plant, MIC underground tanks, storage area and plant control room. Subsequent to the departure of Mr. Sathe, further discussions were also held with the Factory Manager and the Assistant Manager and it was found for the first time that a further 15 tonnes of MIC was present in the second tank No. 611 and this could also be involved in a further release of toxic material at any time. This further posed a new hazard to a large number of visitors, police and civil officials in the factory and in the vicinity outside the factory as well as to

general public especially as the risk of this materials was not known to them. The general public had also no knowledge of what precautions are to be observed in the event of further leakage of toxic material.

Action Taken-

The actions taken cover the following-

i) Examination of the environment immediately to see whether toxic material was present,

ii) If so what further precautions should be taken and advice given to the STate Government and through them to the public,

iii) Action to be taken to estimate the probability of further leakage of toxic material and if possible to prevent such an event;

iv) In the event of leakage occurring, precautions to be taken on minimising the damage to those present in the factory and to public outside including possibility of evacaution of population.

v) Actions on safe disposal of the remaining MIC and any other toxic material found in the factory;

vi) Immediate examination of post-mortem cases, animal carcasses as well as those affected otherwise so that full scientific observations could be made at this critical time for future examination.

viii) Coordination of all scientific efforts and arrangements for information release so that only authoritative data is given to press, to the State and Central Governments to avoid confusion and panic.

Notes on all these are recorded below-

(i) Safety of environment

Teams of scientists analysed air and water samples as well as material from various surfaces in the factory and outside and results showed that there was no further MIC in the air or in water and no detectable material on surfaces. The State Government was immediately advised on 5th evening accordingly and this was broadcast on the radio and press notes were also released.

(ii) Precautions to be taken

The people were advised that there was no danger in the air. Water could also be used preferably with the usual precaution of boiling the water as there was some possibility of communicable diseases such as cholera and plague spreading from undisposed bodies and carcasses. Public were also advised that they should wash all foodstuffs or boil them in water. This is because MIC reacts readily with water especially with warm water and it is converted to harmless material. Through these measures the public confidence in the environment was restored. These precautions were repeated for several days and public fears were allayed on consequences from further leakages.

(iii) Estimating the probability of further leakage

Discussions held at the factory on the morning of 5th December showed that there are three stainless steel tanks each of about 60 tonnes capacity. All pipeline connections for filling tanks with MIC from the distillation column of MIC, the pipelines for removal of MIC to reaction vessels or for filling in steel drums, the pipeline for pressurising with nitrogen, the outlet from safety valves to alkali scrubber, were all through a common system. It was also found that tank 610 from which the toxic material leaked and the tank 611 in which further material was present were both filled with varying quantities of MIC during the production of MIC and material produced upto 22nd October had been stored in both these tanks and the filling was done through common pipelines. Material from either of the tanks was taken out from time to time for further processing upto 2nd December. Thus, there was no reason to suspect the quality of the remaining material in tank 611 estimated at 15 tonnes by factory management to be any different from the quality of the material that had been stored in tank 610 and from which toxic material was released on the night of 2nd Dec. There was, therefore, no reason to believe that the hazard in material in tank 611 was any different from the hazards which had already taken place from the material from tank 610. Thus the high risk of further release of toxic material was confirmed by 11.30 hours on 5th December, It was

also confirmed that the alkali scrubber was designed to feed liquid MIC into liquid alkali solution for destruction. If gaseous emissions occur, the alkali scrubber would not at all be adequate to neutralise the material and the gas would leak out. It was also noted that MIC is a liquid under normal room conditions as it has a boiling point of 39°C. The temperature in the tank could be measured only in the portion above the liquid level and it was about 18°C. However, it was stated that the temperatures in the tanks 610 was noted at about 18°C at 2345 hrs. on 2nd December by an operator before a shift change which occurred before 0000 hours. However, the new shift operator noticed the pressure rise from 2310 hours on 2nd December and very soon after gaseous materials leaked out and this leak continued from 2315 hours on 2nd December to about 0115 hours on 3rd December. The pressure release occurred obviously due to rupture of the disc designed to withstand pressure 40 lbs. per sq. inch (just about 2 1/2 atmosphere). The safety valve would have obviously opened. It was also found that the safety valve returned to place after the gas leaked when the pressure had fallen back.

In these circumstances it was noted that there was no opportunity for a slow rise in temperature and pressure in tank 610. It was not unlikely that a similar rapid rise in temperature would occur in tank 611 and there would be insufficient time for warning being given of the impending leakage. There may not be time to feed the liquid material in the alkali scrubber for destruction also.

It was revealed during the discussions with the Factory Manager that phosgene present to the extent of 200 or 300 parts per million in MIC acted as inhibitor for polymerisation. Analysis of MIC in the tank is not normally possible because there are no facilities for drawing out samples. The analyses are generally carried out by drawing samples from pipelines for delivering MIC into the tank or for withdrawing MIC for transfer to reaction vessels.

Based on these discussions and on the general knowledge of chemistry of MIC, it was surmised that the leakage of material could occur by substantial quantity of water reacting with MIC. This is an exothermic reaction. Reaction with a part of the material could raise the temperature well above the 30°C, the boiling point and the remaining MIC could evaporate as a gas rapidly. By calculations, it was noted that 4.5 tonnes of water would be needed to react with 45 tonnes of MIC present in tank 610. However, it was pointed out by Dr. Varadarajan that 1.5 tonnes of water could be sufficient to react with one-third of the MIC and the heat produced from such a reaction could be sufficient to evaporise the remaining 30 tonnes. The reaction of large quantities of water with MIC could produce Tri-methyl Biuret (TMB) or Di-Methyl Urea. (DMU) .

An alternative to the reaction with large quantities of water was polymerisation of MIC. This produces a trimer or a linear polymer depending on the condition for polymerisation. The heat generated in such polymerisation would also allow a third of MIC to polymerise and at the same time evaporate the remaining MIC as a gas. The factory staff, was maintaining that polymerisation could not occur since analysis previously carried out of MIC had always indicated presence of phosgene varying from 200 to 1200 parts per million.

Since tank 610 had been put under the control of CBI and it was considered unwise and risky to attempt opening of the tank, for examination of the material, if any, present in tank 610. In these circumstances, it was not proven whether tank 610 contained any material and if any MIC remained in the tank or if any other material was present.

Dr. Varadarajan recorded these conclusions on the probable causes of gas leakage on a note prepared at 1255 hrs. on 5th December and a copy was handed over to the Factory Manager. It was therefore concluded that there was high risk of any further toxic material being leaked from tank 611. Steps were initiated to have two operators to watch the temperature recording instrument of tank 611 on a continuous shift basis and also to watch pressures so that in the event of any indication of change, warning alarm could be activated and possible steps taken to minimise damage which would undoubtedly be large under the conditions then prevailing.

Later in the evening of the same day discussions were held in the Union Carbide Research Centre, Bhopal with Managing Director Mr. Gokhale and Vice-President Mr. Kamdar

of the Company and with Dr. Srivastava, Director of Research and other Scientific staff of the Research Centre, Dr. Varadarajan asked for some samples drawn earlier in the factory pipelines of MIC were to be analysed in the factory as well as in the Research Centre. MIC was also converted by give Trimer and Linear Polymer. Infra red spectra of these were also recorded. Data on the heat of these reactions and specific heat of MIC and the boiling point of MIC under different pressure were also obtained from literature and reports. These enabled Dr. Varadarajan to establish clearly that the reaction of MIC with large quantities of water or by polymerisation as stated in the recorded note of that morning could result in a large quantity of MIC to become gas at a temperature of 60°C which would lead to rupture of the disc and release of gas. The analytical methods for determination of phosgene were also examined.

After further detailed discussions, the Union Carbide officials stated that a team of four scientists technologists and one occupational health scientist were arriving on 6th December in Bhopal from USA. It was also found that only the factory Manager and the Assistant Manager of Union Carbide India had any knowledge of MIC and its reactions. It was felt that the team proposed by Union Carbide Management was insufficient to provide adequate information and they were finally asked to arrange for a further set of specialists of Union Carbide, USA such as those from research and chemical operation Managers familiar with Bhopal plant and the USA plant to come immediately. This team arrived on 12th December.

Union Carbide were also persuaded to bring from Calcutta one Mr. Parikh who has been previously Assistant Manager in Bhopal.

Additional information was obtained from Union Carbide officials showed that MIC is highly toxic and pure MIC polymerises readily in the presence of iron, copper and other metal catalysts. Commercial MIC was stated to be safe. It was said phosgene is present as inhibitor of polymerisation. No specifications for commercial materials could be obtained. No information was also available from the Union Carbide on even the probable causes of the conditions leading to the leakage.

Further discussions were held with the Union Carbide, USA team on the night of 6th December, 1984. They could not provide any further information on the probable causes of the accident, or of any investigation on previous small accidents wit MIC.

Furthermore, the analytical procedure of Union Carbide determination of phosgene were re-examined by Dr. Varadarajan and he found this was based on conversion of phosgene to hydrogen chloride. On the morning of 7th December, Dr. Varadarajan came to the conclusion that a small quantity of water of the order of 1 kg entering the tank 610 could react first with phosgene present at ppm level and convert it to hydrogen chloride. Hydrogen chloride could itself initiate polymerisation. Chloride can also react with stainless steel and lead to iron impurity which again could cause polymerisation. Further discussions were held on the morning of 7th with the Factory Manager and Assistant Manager and a note was recorded on Dr. Varadarajan's suggestion that the release of toxic material contained in tank 610 was due to small quantities of water. It was established that such small quantities could come from Nitrogen gas obtained by direct pipelines from a neighbouring factory or also from tube and shell condenser used for distillation of MIC in the MIC plant. He was also able to establish by further analyses, that the analytical method employed by Union Carbide could not sufficiently and clearly distinguish between phosgene and hydrogen chloride. This was also confirmed by adding quantities of hydrogen chloride to MIC and estimating phosgene. It was found that at least a proportion of the added hydrogen chloride was reported as phosgene.

The note recorded was also handed over to Union Carbide Manager immediately. It was established by these theories and experiments that adequate amount of phosgene may not necessarily be present in MIC Tank 611 to act as inhibitor and there may also be chloride which could act as initiator of polymerisation. The risk of further reaction and release of toxic gas from tank 611 was therefore very real.

iv) Action for minimising damage due to further leakage-

Since it was clear that there was potential

risk of some further leakage, the State Government was immediately informed on 5th and again on 7th December of such a danger. They were also advised that personnel including police, not needed in the factory should be removed from the factory premises and entry to the factory should be severely restricted. All entries were from then on were to be made by special passes issued by Dr. Varadarajan. These measures took 3 or 4 days to become fully effective. Scientists were posted in the factory under the control of Dr. Varadarajan to ensure observance of precautions.

In cooperation with Shri P.P. Nayyar, Secretary in the Cabinet Sectt. a number of measures were devised to educate the public. All precautions to be taken were noted and a note on 'Dos' and 'DO'NTs' was prepared and handed over to the State Government. State Government was also advised to remove to enclosed buildings and structures, personnel living in slums and open areas in the vicinity of the factory. Public were informed of the risks and were also advised to use wet towels in the event of any indication of further leakage so that MIC breathing could be through wet material and MIC could be retained and destroyed by contact with water. Personnel remaining in the factory were provided towels and water bottles. Arrangements were also made to obtain 100 gas masks from the Navy for use of persons remaining in the factory in the event of further leakage.

During the meeting in Delhi of the Cabinet Committee on Political Affairs during the early hours of (Sunday) 9th December, 1984 risks of further danger to leakage were explained by Dr. Varadarajan, and various measures for protection of the public were approved. In addition for containment of material within the factory immediately several measures were introduced. Arrangements were made to cut out portion of the high level pipeline outlet of the gas in the factory and weld additional pipeline so that the outlet could be brought into a frame structure which was surrounded by a large amount of cloth on all sides. The continuous spray of large inputs of water by special pipes and by fire hoses was maintained so that in the event of any MIC escape, it can first react with water. A set of helicopters and small aircraft were also brought in for spraying water and to neutralise the gas through large quantity of water if and when any untoward event occured. The factory area and surrounding areas were continuously sprayed with water. The factory compound was covered up to a practical height with special stands and wet cloth material.

In addition, a special Wireless Communication System was established between the Factory, the control room at the State Sectt. Another control room established in the BHEL Guest House. A Hot line between the BHEL Guest House to the office and residence of Cabinet Secretary at Delhi was also established. A 24 hour operation Communication Cell was established in CSIR Headquarters at New Delhi. A 'No Delay Demand Telephone Service' from Bhopal to other points was also established from the BHEL Guest House Control Room.

Additional BSF aircraft and helicopters were also made available by the Cabinet Sectt. for bringing personnel and material to Bhopal.

A Special Officer was appointed by the State Government at the BHEL Guest Room Control Room to coordinate communications and for attending to emergencies. A similar Cell was established with officers of the State Government at the Sectt. Control Room.

v) Action for Safe Disposal of Material of MIC:

The following alternatives were considered for safe disposal of MIC:

i) Removal of liquid MIC under pressure using nitrogen and dumping into a very large volume of water. No arrangements for larger quantity of water in a contained environment can be made. This was therefore not feasible.

ii) The transfer of liquid MIC to the liquid alkaline solution in the alkali scrubber:

While this could be carried out, it was found that MIC contained 1% or more of chloroform and this would react to product carbene. Even a tiny quantity of carbene produces an obnoxious odour. Larger quantities will produce very undesirable odour. This might create panic exodus and stampede in the population. This method of destroying MIC could be resorted to in

an emergency if the temperature and pressure in the tank increased at any time but it was decided not desirable if other alternatives could be found. Nevertheless adequate supply of alkali was arranged to be brought to the factory and stored for use. It was estimated that the disposal of MIC through alkali scrubber might involve an operation of 6 to 8 days.

iii) Conversion of MIC Carbaryl products by reaction of alpha Naphthol:

This was considered the best procedure as factory staff were trained for this operation and facilities including instrumentation were available. Arrangements were made to release alpha Naphthol impounded by Customs in Bombay (about 30 tonnes) and brought by a convoy of lorries with Police escort to Bhopal. Adequacy of supplies of solvent catalysts and other materials was ensured.

Union Carbide, USA team as well as the Chairman of Union Carbide, USA were urging the MIC material was stable and it should be processed immediately from 6th December onwards. Through a detailed study of all factors, Dr. Varadarajan came to the conclusion that the risk of untoward leakage existed at all times and processing of MIC would involve disturbance of the tank by supply of Nitrogen. In the event of sudden reaction, precautionary measures outlined in the earlier sections available before 10 days. The public also would not be adequately informed to take precautions. It was decided by Dr. Varadarajan that it would be better to institute a number of measures within the factory, in the immediate vicinity of the factory, and for the public at large before processing is started. It was agreed with the Chief Minister that notice of seventy two hours be given before processing commenced. A series of discussions were also held with the factory management as well as Union Carbide Corporation team on the relative risks involved in the starting of processing around 7th December or a few days later. As a result, it was possible to come to an unanimous conclusion that the least risk alternative was to process the MIC for conversion to Carbaryl from the morning of Sunday the 16th December, 1984.

Prior to that date, all precautionary measures mentioned in the earlier sections could be fully completed. It was decided that every action would have the approval of Dr. Varadarajan and the team of scientists and technologists assembled by him. It also provided an opportunity for informing the factory staff and arrange for their return, restoration of confidence and completion of further measures in the factory for operations.

A formal communication from Union Carbide, USA team was accordingly recorded on 12th December, 1984 and addressed to Dr. Varadarajan, fully agreeing with the measures proposed by him. Subsequently, the Chairman of Union Carbide, USA also sent a communication to Foreign Secretary withdrawing his earlier suggestion on starting processing on 6th December and fully endorsing the actions proposed by Dr. Varadarajan namely starting operations on 16th December.

Since it was felt that the ingress of small quantities of water and metal contamination could arise from inlets into tank 611 from connections to the reactor distillation unit and from the nitrogen supply. All existing pipeline connections were closed or removed. A new Nitrogen pipeline was established. Visits were made to the Nitrogen providing factory and analytical procedure for nitrogen Institute. In the pipeline system drying agents and filters were introduced to ensure high purity. All measures were recorded and instructions issued and changes were carried out under the supervision of Scientists team.

The information on starting of these operations was provided through a Broadcast by the Chief Minister on 12th December, 1984. Those who felt it was unsafe to stay, arranged to leave Bhopal and it is estimated about 80,000 persons left Bhopal but in an orderly manner. Additional trains and transport were arranged to facilitate movement. About 6,000 to 10,000 people who were living in open areas were provided shelter in Schools and other buildings by State Government.

Detailed information on the operations proposed was provided in a Press Conference by Dr. Varadarajan on 15th December, 1984 to about 300 Press Correspondents. Two parties of Press representatives of 25 persons each were

taken to the Factory under supervision and detailed measures deployed were exhibited so that full and correct information could be provided.

Operations started on the morning of 16th December and were completed on 22nd December, 1984. All instruments were replaced by no defect instruments. At one stage the addition of phosgene to the MIC in tank 611 was considered as a method of improving the stability and phosgene was brought in by helicopter from Bulsar. At this stage an additional team from USA arrived and they were not able to give any assurance that phosgene itself acted as an inhibitor for polymerisation. Although arrangements were made for purifying phosgene so that it is metal free and provision for adding this material with due precautions to the tank were made, on receiving information of uncertainty of this acting as an inhibitor, it was decided not to proceed with the addition of phosgene.

Immediately after 5th December, arrangements were also made to establish four weather monitoring stations with the cooperation of India Meteorological Department. Two hourly observations were made in the stations on temperature, wind velocity and wind direction. With this information, it was possible to know direction of wind and on the probability of inversions occuring. Inversions tend to contain any toxic material released for long periods. With information on wind direction, it was also possible to have a system for warning specific wards and areas in the city of Bhopal in the event of any untoward release of toxic material. The same system was used throughout the period of operations of conversion of MIC into carbaryl. In addition, a system of detection of MIC in air was established in the factory so that even small release of MIC could be detected. No MIC was found throughout this period.

At one stage there were reports from some investigators, not forming part of the team, that cyanide levels in air in excess of permissible limits were detected. A large investigation was carried out to see if this could be verified by using special tubes for detection of minute amount of cyanide, flown in from IPCL Baroda along with appropriate experts. Throughout the period, no cyanide was detected in the air. The liquid level indicator in tank 611 and the empty tank 619 were not functioning and was learnt that these were sealed by CBI. The estimates of MIC were made from the records provided by the factory management. However, after the first day operation on 16th December, it was possible to judge quickly from the gas pressure of tank 610 that the material present in tank 611 was in excess by about 4 tonnes. Adequate arrangements were made to ensure availability of alpha naphthol for conversion of the additional material. Similarly note was taken of the MIC material (about 1.2 tonnes) stored in sealed drums. Special arrangements were then instituted for drawing material from such drums. The tank 619 was also found to contain over 2 tonnes of material. This was also withdrawn and converted. The operations had therefore to be extended by about 2 days. About 3-4 tonnes could be processed each day. The transfer of MIC from tank was done during day light hours and conversion to carboryl was carried out throughout the night. Representatives of Scientists' team were present throughout this operation day and night and operations for each transfer of material were approved by Dr. Varadarajan and the team. Trial reactions in the factory laboratory were carried out with material in tank 611, 619 and drums separately to ensure these materials would fully react with alpha naphthol. Transfering of bulk materials were approved after such trials in each case.

Throughout this period, adequate precautions for spraying water and for test flights of aircraft for sprays were continued. Special arrangements were also made at the airport for communications so that in the event of any leakage, aircraft could be brought in for action. The entry into the factory of personnel, material and vehicles was strictly controlled throughout this period. Reports on the progress of operations were made twice a day to the press during the initial three days and subsequently once a day. As the material in tanks was used up, the level of potential damage decreased and once all the tank material was utilised, it was possible to declare that the environment would be safe. As MIC was present only in 180 Kg. steel drums. Finally all pipelines were drained off of MIC and used during the entire period, the alkali scrubber was operated.

(vi) Assistance to health and medical authorities

Scientists from All India Instt. of Medical

Sciences, Patel Chest Institute and Indian Council of Medical Research visited and stayed for substantial periods in Bhopal. They visited hospitals and had discussions with the Director of Medical Services and the Heads of hospitals and were able to monitor the treatment given for heavy toxicity affecting lungs as well as to those whose eyes were effected. A wealth of information was obtained from observations as well as from the post mortem examinations. This will be of considerable value in future. Special assistance was also given for analysis of materials drawn from patients and also during post mortem examination.

A number of foreign medical personnel had also visited Bhopal and were offering advice Discussions were also held with such medical scientists from Germany, USA, France and Scandanavian countries.

(vii) Collection of materials for future examination

Arrangements were made for collecting material from post mortem examination and organs and tissues have been preserved along with data on symptoms and conditions of patients before death. Additional material from animal carcasses has also been collected. The histories of patients and if the dead from whom collection of samples was made, has also been recorded so that the effects of MIC over a period of exposure could be examined. Later on, there were also certain delayed effects and return of patients and observations have been made on them.

Samples have also been collected of plant specimens, leaves etc. Observations have been made to see if any deterioration has not taken place. These materials are also being analysed by ICAR as well as CSIR Laboratories.

(viii) Coordination of efforts:

As mentioned earlier a Coordinating Cell for this purpose was set up in RRL, Bhopal where a meeting of all scientific groups were held at 1400 hours daily. Written reports were made by each group every day. These have been collected and oral reports were also made in such meetings. As a result some additional tasks were also given to scientific groups.

Special arrangements were also made to have scientific groups from ICMR, Patel Chest Institute, AIIMS, National Institute of Nutrition, Indian Cancer Research Centre, Indian Agricultural Research Institute and other institutions of ICAR, the Defence Research Laboratories in addition to those from CSIR Laboratories. Visits by Director-General, ICMR, Additional Director-General, ICMR, Adviser (Biotechnology), Department of Science & Technology, Adviser (Chemicals) and other officials from Ministry of Chemicals and Fertilizers were also arranged. Extensive investigations were also conducted by the Additional Director-General, ICMR. Special arrangements were also made for reserving certain number of seats on IAC flights between Delhi and Bhopal and for the reception of personnel accommodation and transport. Laboratory facilities were also provided at RRL, Bhopal.

The various institutes were asked to make literature surveys regarding the toxic effects of MIC and related isocynates and a large amount of material became available. In addition material has been received from international organisations and research institutes.

Throughout this period, the Scientists of CSIR carried out a large number of analyses in the factory and in the research centre of UCIL Bhopal. These analytical results proved useful in drawing up the course of action in the processing of MIC and in estimating the risk.

Towards the end of operations for conversion of MIC, it was decided to open the safety valve and the section connected to tank 610 after taking necessary precautions. A certain amount of solid material has been replaced. The original safety valve and the ruptured disc have been handed over t CBI. The material collected from this section has been subjected to preliminary investigation in CSIR Laboratories and in the IPCL Research Centre. From this, appears there is no TUB or TMB present. Most of the material consists of trimmer and there is some amount of volatiles. No DMU or TMB has been found. The examinations are being carried out and results of which are awaited. Analysis for trace metals has also been made and presence of metals has been recorded. Small quantity of material from inside the tank 610 has also been recovered for examination which is in progress. However immediately after these

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efforts, in the case of petition filed by some citizens of Madhya Pradesh, the High Court ordered that tank 610 should not be opened and no further examination be made.

From the examination made so far it appears that the incident in tank 610 took place as a result of polymerisation and not due to the input of large quantities of water. It appears that there was rapid polymerisation of a portion of the material and the temperature may have risen over 100°C, possibly 150°C. This high pressure and temperature was obviously maintained in the tank after rupturing of disc and lifting off safety valve. This could be possible because of the pipeline leading to the alkali scrubber allowed only the outflow of the gaseous material at a certain rate and the tank maintained high temperature well over 100 degrees for more than 1 to 1½ hours. It appears some thermal cracking could have also occurred because of such high temperature. This could lead to conversion of MIC to polymer and some other products such as methylamine, ammonia and dimethylamine. A strong smell of ammonia and amones was noted from the solid samples found from the safety valve section. The trimer melts at these high temperature and could have volatalised and crystallised in the tube section of the safety valve. Further hypotheses of the actual occurrence has to await fuller recovery of the material in tank 610 and determination of the total quantity of such material left in the tank.

The High Court passed orders that three lots of 5 Kg. samples from tank 611 should be preserved. Scientific reports were supplied to the Court through the State Government stating that there are no facilities for storing such large quantities and it would be unsafe to store them in glass bottles or containers. Subsequently the High Court passed orders that 5 samples of 300 gms. each should be preserved for future examination. Although the risk is there, the orders have been complied with and the material has been stored in glass bottles with covers for holding the pressure. Such material can polymerise any time and can release gaseous MIC' Adequate precautions have been taken and staff have been warned about such a risk. The High Court appears to have passed an order that detailed examination of these samples should be made in the presence of two groups of scientists one from CSIR and one from Bhabha Atomic Research Centre and these scientists should be named by Dr. Varadarajan. Detailed information is awaited

Since the senior factory staff were under arrest and confined to factory premises, orders for start of operations could not be issued by them. They cooperated fully with the team of the Government despite these restrictions. It was necessary that the factory operations were carried out with senior factory staff acting on their own free will. The release of these staff on bail was requested by Dr. Varadarajan and a communication was sent to Chief Secretary. The Court then arranged the release of these staff for a limited period covering the time of operations for conversion of MIC. Although factory staff was reluctant to avail of bail under such restrictions but they were persuaded by Dr. Varadarajan to accept these conditions.

Constant communications were maintained with the Cabinet Secretary and other officials of the Central Government, State Government and the Chief Minister. A meeting was also held with Mr. Soares, a Congressman from USA and the officials of the U.S. Embassy in Delhi who visited Bhopal.

Since the Chairman of Union Carbide USA had been sending messages regarding the risk of remaining material and urging processing this material from 6th, it was arranged for the Foreign Secretary to send a message to the Chairman, Union Carbide of USA asking him to send specifications of material which could be considered safe and methods of analysis of such materials. He was also informed by the Foreign Secretary that in the opinion of Dr. Varadarajan there were high risks in processing materials from 6th and precaution could not be adequately ensured for minimising the risks within the factory and to the population in Bhopal who were unprepared for such risks. No reply was received regarding specifications or tests. However, Chairman, Union Carbide USA finally sent a message endorsing actions proposed for conversion of material from 16th.

Concluding remarks

These very large set of operations would not have been possible but for the large amount of interest and cooperation and series of measures taken by the Cabinet Secretary, Ministry of Chemicals and Fertilizers, Ministry of Home

Affairs, Ministry of Health, Ministry of Law and Ministry of External Affairs. In addition ready cooperation was obtained from scientists from laboratories of CSIR, ICMR, ICAR as well as from organisations such as IPCL Baroda, Hindustan Organic Chemicals, Rasayani and Indian Drugs and Pharmaceuticals. In addition distinguished scientists such as Professor M.M. Sharma of the University Department of Chemical Technology, Bombay and Professor A.S. Paintal, Vallabhbhai Patel Chest Institute, Delhi readily agreed to visit Bhopal and have discussions and give their advice. The STate Government provided a great deal of help. The authorities of BHEL at Bhopal provided unstinted support for accommodation and other facilities in their guest house and for examination at hospitals. In addition the Air Force, Army, Navy and the BSF readily gave help in various ways. The Agricultural Pesticide Spraying Service was also called into operation. The senior staff of the factory of Union Carbide Ltd. at Bhopal gave unstinted cooperation and worked continuously for very long periods and accepted the overall supervision of the scientific team. The scientists at the UCL Research Centre also gave help in carrying out a number of analyses.

Similarly the Headquarters' staff of CSIR also maintained communication links and coordinating efforts at Delhi and at Bhopal. Large efforts were made by the Scientists at RRL-Bhopal. The operations of this nature could not have been carried out without the willing and sustained efforts of all those mentioned and all thanks and gratitude are due to all of them.

(S. Varadarajan)
Director General, C.S.I.R.
& Secretary to the Government of India

New Delhi, the 9th January, 1985.

Annexure - I

List of Scientists who participated in the follow-up actions at Bhopal after the UCIL accident in December, 1984.

Council of Scientific & Industrial Research, Rafi Marg, New Delhi.
- Dr. S. Varadarajan
- Dr. Lata Singh
- Shri M.V. Ramakrishnan

Regional REsearch Laboratory (CSIR), Bhopal
- Prof. P.K. Rohatgi
- Dr. M. Patel
- Dr. C.B. Raju
- Dr. A.K. Ray
- Dr. (Mrs.) M. Maheswari
- Mr. Amrit Phale
- Mr. B. Kujur
- Miss A. Gupta
- Mr. A.C. Karara
- Mr. A. Khare
- Mr. J. Jain
- Dr. Ravi Prakash
- Mr. Krishna Kumar
- Mr. K.K.S. Gautam
- Mr. A.C. Khazanchi

National Environmental Engineering Research Institute (CSIR), Nagpur.
- Dr. K.R. Bulusu
- Dr. P.K. Yennawar
- Dr. A. Ghosh
- Dr. M.Z. Hasan
- Dr. D.M. Dharmadhikari
- Mr. Pento Saheb

Regional Research Laboratory (CSIR), Hyderabad.
- Dr. G. Thyagarajan
- Dr. Negabhushan Rao
- Dr. S. Koteswara Rao
- Dr. Asad Ali Khan

National Chemical Laboratory (CSIR), Pune.
- Dr. R.A. Mashelkar
- Dr.N.R. Iyangar
- Dr. O.G.B. Nambiar
- Dr. Nadkarni

Industrial Toxicology Research Centre (CSIR), Lucknow.
- Dr. M.M. Lal
- Dr. N.K. Mehrotra
- Dr. M.U. Beg
- Dr. S.K. Bhargava
- Dr.M.M. Kidwai
- Dr. R.P. Saxena
- Dr. Mohd. Farooq

Indian Council of Medical Research, New Delhi.
- Dr. V. Ramalingaswami
- Dr. A.B. Mitra
- Dr. H. Bhandari
- Dr. S. Sriramachari

Institute of Pathology, New Delhi.
- Dr. H.M.K. Saxena

National Institute of Occupational Health, Ahmedabad.
- Dr. S.K. Kashyap

Safdarjung Hospital, New Delhi
- Dr. B. Dasgupta

Patel Chest Institute, New Delhi
- Dr. A.S. Paintal
- Dr. S.K. Jain

Indian Council of Agricultural REsearch, New Delhi.
- Dr. S.K. Mukherjee
- Dr. H.K. Roy
- Dr. T.P. Sriharan
- Dr. A.K. Dikshit
- Dr. N.N. Pandey
- Dr. Y.P. Singh
- Dr. A.E. Nivsarkar
- Dr. S.N. Dwivedi
- Dr. H.K. Vardia
- Shri Jiya Lal Ram
- Dr. Chandra Prakash
- Dr. K. Bhavan Narayanan