UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORK

SAHU, *et al.*,	:	Index No. 07 Civ 2156 (JFK)
Plaintiff,	:	
-against-	:	**DECLARATION OF DR. IAN VON LINDERN IN OPPOSITION TO DEFENDANTS' MOTION FOR SUMMARY JUDGMENT AND IN SUPPORT OF PLAINTIFFS' MOTION PURSUANT TO FEDERAL RULE OF CIVIL PROCEDURE 56(d)**
UNION CARBIDE CORPORATION, *et al.*,	:	
Defendant.	:	

Declaration of Ian H. von Lindern
Regarding Review of the Design of the Union Carbide Corporation (UCC) / Union Carbide India Ltd. (UCIL) Pesticide Production Facility, Bhopal Madhya Pradesh, India

1. My name is Ian H. von Lindern, I have been Principal Scientist and Chief Executive of TerraGraphics Environmental Engineering located in Moscow, Idaho since 1984. TerraGraphics has provided specialized environmental services at hazardous waste sites for thirty years. TerraGraphics' experience and expertise includes site characterization, risk assessment, evaluation of cleanup alternatives, feasibility studies, engineering design, remedial oversight, site restoration and construction management.

2. My academic training includes a Bachelor of Science degree in Chemical Engineering from Carnegie-Mellon University in Pittsburgh, Pennsylvania and Masters and Ph.D.degrees in Environmental Science and Engineering from Yale University in New Haven, Connecticut. I have been a licensed Professional Engineer in Idaho since 1975, and an Adjunct Professor of Chemical Engineering at the University of Idaho since 1984.

3. I have 40 years of environmental engineering and science experience in the U.S. and internationally. I have directed more than two dozen major environmental investigations, involving solvent, metals and synthetic organic chemical contamination of soils and groundwater; agricultural chemical plants; petro-chemical spills; an abandoned petroleum refinery; nuclear waste sites; secondary smelters and battery processors; landfills; uranium mill tailings; and several major mining/milling and primary smelter sites. These projects have been located in a number of States and international locations including Canada, Australia, Africa, the Russian Far East, China, the Dominican Republic, Senegal and Nigeria.

4. I have been an employee, Project Manager, and consultant to the State of Idaho, the U.S. Environmental Protection Agency, local governments and the Coeur d'Alene Tribe at the Bunker Hill/Coeur d'Alene Basin Superfund Project in northern Idaho for thirty years. This was the scene of one of the largest epidemics of childhood lead poisoning associated with an industrial source ever documented. Ninety-nine percent of the children living within a mile of the plant were poisoned following the smelter owner's decision to continue operations following a fire in their main pollution control facility in 1973. In total, more than 1000 children were poisoned. Twenty-five percent of children in the same area continued to be lead poisoned by the residual soil and dust contamination in the community following closure of the industrial complex in 1981. Since the early 1980's, this has been one of the largest and most complex contaminated site cleanup projects undertaken by the United States Environmental Protection Agency. Today, following the human health cleanup, children's blood lead levels are similar to those throughout the rural U.S., and the community is undergoing economic redevelopment.

5. During the 1970's, contemporaneous with the activities and materials reviewed in this report, I was the regional pollution control engineer for the State of Idaho. In that capacity I conducted numerous design reviews of industrial and municipal waste treatment systems. I participated in compliance and wastewater characterization studies similar to that referenced below for the Union Carbide Corportation (UCC) facility in Institute, West Virginia.

6. I have assisted the State, federal and local governments in executing nearly every phase of site cleanup activity ranging from emergency response, to site characterization, risk assessment and risk management planning, evaluating and designing cleanup alternatives, overseeing cleanup and infrastructure construction, and integrating cleanup and restoration activities into community redevelopment plans. In that capacity, I published articles and reports and served on Advisory boards and panels, including on five occasions, as a consultant to the U.S. EPA Science Advisory Board. I represented the State of Idaho before a National Academy of Science (NAS) Panel assessment of the cleanup activities in the Coeur d'Alene Basin.

7. Most recently, I am co-founder and Executive Director of TerraGraphics International Foundation (TIFO). TIFO provides humanitarian assistance to governments, Non-government Organizations (NGOs) and local communities in developing countries with health and environmental risk assessment, mitigation and cleanup. In 2011, TerraGraphics received the biennial GreenStar award from the United Nations Environmental Program (UNEP) for outstanding humanitarian service in response to environmental emergencies. Over the last four years, TIFO and TerraGraphics assisted the Nigerian governments and the NGO Medicines Sans Frontiers (MSF) in one of the largest environmental lead poisoning remediation and treatment projects undertaken in Africa. More than 500 children died in the first six months of the epidemic in 2010. The combined efforts of the Nigerian governments, MSF, the U.S. Centers for Disease Control (CDC), World Health Organization (WHO), MSF, other NGOs, TerraGraphics and TIFO have been successful in remediating the homes and villages of more than 16,000 victims of lead poisoning and provided treatment to more than 3500 children under five years of age at severe risk of mortality, brain damage, and other irreversible health effects. More than 800 home compounds were remediated in eight villages spanning 1000 square miles in one of the most remote and logistically challenging regions of Africa. TerraGraphics and TIFO assessed, designed and assisted the governments in implementing the remediation activities, trained and provided guidance to more than 100 government health and environmental professionals and 500 village workers, local contractors, and suppliers engaged in the cleanup. I served as Project manager for those activities.

8. My resume is attached and includes publications for the last ten years. In the last four years I have submitted expert reports and was deposed in the matter of PAKOOTAS et al. and STATE OF WASHINGTON, Plaintiff-Intervenor v.

TECK COMINCO METALS, LTD., a Canadian corporation, Defendant. No. CV-04-256-LRS. UNITED STATES DISTRICT COURT EASTERN DISTRICT OF WASHINGTON. My rate for this case is $250/hr for reports, and $350/hr for trial and deposition.

Background:

9. I have been requested by counsel for the plaintiffs to review documents related to the design construction and operations of the former Union Carbide India Limited (UCIL) facility in Bhopal, Madhya Pradesh, India. I have reviewed the following material with the objective of assessing the role of Union Carbide Corporation (UCC), and UCC engineering groups in the design process for the Bhopal plant, and specifically UCC's role in the selection, specification, design, and ultimate performance of the waste treatment concept, philosophy, implementation and performance. I have been specifically requested to comment on:

   i) Whether, from a waste-management perspective, waste disposal can be effectively separated from waste generation, and whether waste system design be separated from production and manufacturing process design?

   ii) If a manufacturing technology produces wastes that cannot be properly disposed of at that particular site, then is the manufacturing technology inappropriate for the site?

   iii) Whether UCC played a significant role in the development, adoption, design and implementation of the waste treatment strategies employed at Bhopal?

   iv) Whether UCC's participation in waste treatment design influenced the reliability and risks associated with the eventual implementation and performance of the waste treatment system.

Findings:

<u>General Comments and Conclusions</u>

10. Consideration of wastes generated, and inclusion of appropriate waste management facilities, is an inherent responsibility in the design and operation of any industrial manufacturing process. That responsibility is critical in the case of processes that produce toxic and hazardous wastes, such as those utilized at the UCIL pesticide plant in Bhopal. Proper management and disposal of wastes is an integral element of the manufacturing facility that cannot be separated from the overall design.

11. Numerous design determinations made in the manufacturing process influence the quantity and chemical and physical characteristics of by-products and wastes;

and, in turn, predetermine the design requirements and constraints on the waste management systems. Proper handling of wastes in a manner protective of public health and the environment can be expensive, pointing plant economics towards recovery, reuse and recycling of by-product and waste materials. These considerations are simultaneously important to the design of both the product manufacture and waste management processes.

12. The effectiveness of the recovery, re-use and recycling of these materials can have significant effects on the product manufacturing processes, waste treatment, and the ultimate need for disposal. The product manufacturing processes determine the waste and by-product characteristics that influence the efficacy of the treatment, recovery and disposal processes. In turn, the efficiency of the recovery and treatment operations determine the efficacy of by-product and waste recovery and reuse; thus setting up constant feedback loops that are integral to, and not separable from, the manufacturing process.

13. In plant operations, these feedback loops are inherently designed into the manufacturing process and are integral to plant design and economics. Although critical to the waste management strategy, many of these process steps are not readily apparent as components of the waste management system when the plant is operating efficiently. However, upsets and malfunctions during the manufacturing processes that can disrupt these operations have significant and sometimes overwhelming effects on the waste treatment facilities; as by-products, intermediate-products, wastes, and sometimes raw materials are discharged or by-passed to, or sometimes around, the waste treatment streams.

14. It is an inherent design responsibility to appropriately project and accommodate these excursions in waste generation. Often the solutions to these challenges are found in modifications to the processes, as opposed to increasing the treatment capacity. As a result, process engineering and design are never far removed, and are generally not separable, from pollution control.

15. As a result, in answer to question i): The waste management system includes waste generation, treatment, and disposal. These elements are not separable in the development of effective and efficient waste management strategies, or in the design of any element in that strategy. In answer to question ii) If proper and adequate waste treatment and disposal systems cannot be applied to particular manufacturing processes at a site, then it is inappropriate to employ those processes.

16. In answer to question iii): It is important to point out the General Operating Manual developed in 1997 for the UCC/UCIL Bhopal facility endorses the principle that the waste management system encompasses the entire plant, is not limited to the disposal facilities per se, and is not separable from the manufacturing processes. The Manual notes that the premier consideration in the overall waste management strategy is "sharp" operations that avoid upsets and

malfunctions and minimize the production of undesirable wastes. The manual also notes concern with developing effective waste management practices due to uncertainties and potential upsets and malfunctions in UCC's new and commercially untested manufacturing processes. (A-227).

17. The record developed below clearly shows the UCC played the dominant and lead role in development of the waste management strategy and the design of the overall waste management system. UCC developed the waste management strategy and incorporated it into the basis of final design. Errors made by UCC in the preliminary stages of design necessitated major modifications in the final designs of the project. The most significant changes were in waste generation effected in the manufacturing processes provided and designed by UCC.

18. In answer to question iv): UCC did delegate some design functions to UCIL including one element of the waste management system - waste disposal. However, UCC retained review and approval authority for final design and rejected UCIL's proposed modifications when the error was discovered and provided an alternate design. In addition, UCC provided the design parameters, waste quantities, and waste characteristics to UCIL, effectively limiting UCIL's role to specifying UCC design requirements to local conditions.

19. More important, the changes made in the manufacturing and treatment processes by UCC introduced uncertainties in the quantities and characteristics of waste streams. There is no evidence in the records reviewed that UCC adequately conveyed these uncertainties to UCIL in the design parameters. The uncertainties associated with UCC's manufacturing processes offered the greatest risk of failure of the waste management system that ultimately resulted in contamination of the local environment and ongoing risk to public health.

UCC's Engineering Role in the Design and Operation of Waste Disposal at Bhopal

20. UCC was involved and played an instrumental role in the selection, strategy, design and implementation of the waste treatment system at Bhopal from beginning to implementation and operation. UCC conducted the feasibility studies. UCC concluded that the major components of the UCC pesticide plant at Institute, West Virginia were applicable to the Bhopal site, and the UCC design could be extended to Bhopal with modifications dependent on local and site conditions in India.

21. In extending the design of the Institute, West Virginia facility to Bhopal, UCC recognized the unavailability of large receiving waters for waste disposal was a major design constraint. UCC conducted feasibility analyses and selected a neutralization / solar evaporation pond (SEP) strategy to dispose of waste and waste water from the facility. UCC recognized the local groundwater was a known source of drinking water for the village populations surrounding the plant. UCC engineers recognized that the evaporation capacity of the SEP had to exceed

the wastewater inflow, particularly in the monsoon season, to prevent overflow and subsequent contamination of the groundwater. UCC recognized that the SEP bottoms should be lined and constructed to eliminate significant seepage and leaks. UCC engineers recognized the corrosive nature of certain waste streams would render the waste management and disposal processes ineffective, and selected a neutralizing process to render the discharge suitable for discharge to SEP. The UCC design team conducted or reviewed economic analyses of available raw materials in the Bhopal region in selecting and determining the process to be used in pre-treating the acid-waste stream.

22. The UCC waste management strategy and preliminary design documents were adopted as the basis of design for the waste treatment system, with certain qualifications that the basic assumptions regarding the evaporation rates be verified by onsite tests. UCC provided the Project Manager for the final design effort. UCC was assigned lead responsibility for those product manufacturing processes that produced the bulk of wastes from the facility requiring treatment in the waste disposal system. UCC engineers had review and approval authority for any modifications that UCIL would propose for UCC designed processes.

23. UCC engineers provided specifications for testing the basic waste treatment design assumptions. Those tests subsequently showed that UCC's initial assumption were grossly in error. The evaporation potential was only 35% of UCC's design assumptions. UCIL proposed an alternate strategy abandoning the UCC basic design requirement that the SEP accommodate the entire waste hydraulic load. UCC indicated that UCIL's proposal was ill-advised and provided recommendations for alternate pond sizing. Had the on-site evaporation rates been available during the feasibility phase, there is significant question as to whether the SEP strategy would have been selected. The UCC neutralization /SEP strategy was subsequently salvaged by modifications to the UCC processes that substantially reduced the projected waste loads, decreasing the amount of water discharged to, and the evaporation requirement, at the SEP. However, these modifications were, in several cases not commercially proven technologies, and contributed to the uncertainties, risks and reliability of the waste production, treatment and disposal.

24. According to the design protocol agreement with UCIL, UCC either designed or approved these modifications. These and other changes were recognized as new and unproven technologies and presented a risk of waste treatment difficulties, especially those associated with upsets, malfunctions, start-up, shut-downs, and utility failures. UCC provided trained personnel from the Institute, West Virginia plant to assist with the startup operations.

25. Although UCC was able to modify the manufacturing processes to reduce waste water flows to levels that potentially could accommodate the hydraulic load, the waste treatment system lacked the resiliency of the Institute, West Virginia plant. In West Virginia, the waste streams were discharged to a wastewater treatment

plant that provided for emergency storage, primary and secondary clarification, equalization, aeration, neutralization, sludge thickening, and sludge storage ponds. The wastewater treatment plant discharged to the river following secondary treatment and clarification.

26. The combination of the treatment plant and river discharge at Institute offered significant operational flexibility and dilution capacity to accommodate waste discharges, and particularly atypical loads associated with upsets and malfunctions. Moreover, the river offered a continuing supply of free-flowing dilution water that mitigated and carried away any materials normally, or atypically, disposed in the discharge. Although the downstream aquatic environment may have suffered, the upstream river continued to deliver this fresh resource to the Institute plant to exploit. Despite the capabilities of UCC's Institute facility, an intensive pollution control study conducted by the U.S. Environmental Protection Agency in 1977-78 showed the UCC Institute plant failed to meet its pollution discharge permit the majority of months surveyed, and noted an unusual amount of leaks in the same operations advanced to Bhopal, due the extremely corrosive conditions. (USEPA-NEIC 1979)

27. In contrast to the U.S. plant, the SEP design at Bhopal had little inherent flexibility to accept and retain the plant discharges, and, in turn, released those toxins it could not accommodate to the adjacent land and groundwater. Major upsets, malfunctions, and bypasses - that were diluted and pre-treated in the waste treatment plant and carried away by the river at Institute - could shorten the design life and permanently damage and adversely affect the efficiency of the SEP in Bhopal. UCC was well aware of prognosis for upsets and malfunctions associated with the unproven technology at Bhopal. Much of that risk and uncertainty was associated by the process modifications UCC instituted to accommodate the evaporation limitations at the SEP through modification of UCC processes. UCC was certainly aware of, and self-reported, the USEPA's findings regarding discharge permit violations at the Institute plant that utilized proven processes.

28. This combination of uncertain waste loads and lack of resiliency at the SEP was a major concern for the efficacy of the waste treatment strategy at Bhopal, and likely contributed to the failure of the system and subsequent contamination of the site. UCC was responsible for the waste treatment strategy, selection of the neutralization/SEP waste treatment system, the design of the manufacturing process modifications necessitated to accommodate the capacity of the SEP, which UCC had overestimated by a factor of three during development of the basis of final design documents. UCC provided the design parameters and waste load projections for the waste disposal system design in India.

29. The result of the UCC design analyses was that the UCC design team selected and mandated the waste treatment strategy, the UCC design team determined the major components of the overall waste treatment facilities and the degree to

which the efficacy of the waste treatment facilities would depend on the operations of the product manufacturing processes. The UCC team was clearly responsible for those manufacturing processes and the inherent components of waste management strategy embodied in those designs.

30. UCC delegated some design activities normally undertaken by UCC to UCIL. UCC and UCIL entered into a collaborative effort for final design in which UCC was responsible for all manufacturing process design, and would provide UCIL with the design criteria and specifications for the water and neutralized waste disposal system. UCIL would then complete the final sizing and on-site design for the SEP. UCIL was required to submit suggested modifications as change reports to UCC for review and approval. UCC subsequently reviewed and dis-approved UCIL proposals regarding pond sizing and issued alternate recommendations.

31. This arrangement makes sense from the perspective that local engineers could best determine the site-specific meteorological, hydrologic, and edaphic conditions in India and work directly with India government officials in sizing, specifying the suitability of local materials and supplies, and constructing the facility in accordance with the UCC design. However, the delegation of selecting and implementing site-specific aspects of certain elements the overall waste management design to local UCIL agents does not relieve the UCC process engineering team of responsibility with regard to the efficacy of the overall waste treatment system.In addition, those design parameters and reports provided to UCIL reflected normal operating conditions. There is no evidence in the documents reviewed that the design criteria included information regarding the potential frequency, magnitude and chemical and physical characteristics of upsets, malfunctions, bypasses and intermediate product releases; nor was there any discussion or recommendations regarding the potential impact these other than typical operations may have, or any mitigation measures necessary to protect the SEP system.

<u>Chronology of UCC's Involvement in the Bhopal Plant Design</u>

32. Engineering design and construction projects are typically undertaken in phases proceeding from the conceptual, investigative, detailed and final design, to construction, startup, and operations. Stages in the design process are typically referred to as feasibility level studies, engineering studies, preliminary design, phased design reports at benchmark intervals (e.g., 30%, 50%, 90% design reports), final design/specifications, construction documents, construction management, inspection and certification.

33. Design projects are generally conducted under the direction of a Project Manager, who manages all technical aspects of the design and construction process.

34. In the case of Bhopal, UCC was continuously involved in all aspects of the design, and provided the Project Manager throughout the entire design and

construction process, and experienced plant personnel from the U.S. in startup operations.

35. **Feasibility Phase:** During the Feasibility Study phase, UCC cited an existing formulation plant, convenience of rail access, accessibility to local materials, and the availability of cheap land as primary considerations in siting the plant at Bhopal. UCC noted the primary disadvantage to the Bhopal site was that no waterway (river) was available as receiving waters for the discharge of wastes. UCC engineers conducted feasibility analyses concluding that the overall design could be based on the operations at UCC's Institute, West Virginia plant in the U.S. with certain modifications. (A-114)

36. With regard to waste treatment and disposal, UCC engineers conducted feasibility analyses of process alternatives to the central treatment plant and river discharge operation at the West Virginia plant. UCC engineers evaluated employing pretreatment neutralization and Solar Evaporation Ponds (SEP) to treat and dispose of liquid wastes from the projected MIC process and others at Bhopal. UCC engineers concluded that pretreatment neutralization and SEP strategy was feasible with certain provisos. Those limitations noted that the groundwater beneath the plant and the proposed SEP location was used as domestic drinking water source by the local population.

37. UCC recognized this fact required that the operations and the ponds not leak contaminants to the groundwater. UCC engineers noted that the final design, construction and operations of the plant would require the ponds i) be lined with materials adequate to prevent leakage, and ii) be sized large enough to accommodate the full hydraulic load and totally evaporate all water in the discharge to prevent overflow. UCC engineers also noted that the feasibility analyses conclusion that the SEP was a viable strategy, was based on assumed soil characteristics and evaporation rates from comparable sites in the U.S. UCC engineers conditioned the neutralization/SEP strategy on verification of the edaphic and climatic suitability of the Bhopal site (i.e., that the local soil and weather conditions were consistent with the design assumptions).

38. **Preliminary Design Phase:** Preliminary design activities were carried on by UCC engineers based on UCC's concurrent operations in Institute, West Virginia. The preliminary design reports emphasized cost and evaluated the site-specific application of the processes used in West Virginia largely on the basis of plant economics. Alternatives to particular aspects and components of the West Virginia operation were considered. Most alternatives were considered due to concerns regarding the capital cost of construction and reliability of local materials and supplies.

39. The non-applicability of the waste treatment strategy employed in West Virginia was continually noted on the basis that no river was available for discharge. Additional analyses of the waste treatment strategy were undertaken and UCC

continued with the selection of the neutralization/SEP strategy despite concerns regarding the capacity of the ponds to prevent leakage and overflows due to local soil and climatic conditions. UCC produced preliminary design reports showing the selected process design components and the selection of the neutralization/SEP strategy for wastewater disposal, and provided recommendations for additional engineering studies to confirm key assumptions made in the preliminary design. (A-156)

40. **Investigative Phase:** During the engineering study phase UCC continued to assess the applicability of the West Virginia operations to Bhopal and the evaluation of alternatives and modifications. Internal UCC memoranda in May 1972 indicate serious concerns by UCC engineers regarding the ongoing design of the waste treatment system. A May 5, 1972 letter to the UCC Houston Center Engineering Division expressed concern regard lack of planning regarding disposal of wastes from the proposed Bhopal plant, an indication the uncertainty was affecting the process design, and a suggestion that the lack of a river to dispose of salts from the acidic wastes could affect the original decision on an inland location for the plant. UCC process engineers indicated they would continue to design the process indicating waste flows identical to those at the Institute, West Virginia plant. They also noted that UCC may have lost a license competition at another India location due to advocating processes with similar waste discharge characteristics. (UCC04514)

41. Subsequently, a few days later a prominent UCC engineer expressed concerns in an internal memo that proposed modifications to the design approach advocated in the preliminary design reports relied on the "… less advanced environmental consciousness in India" and that "… the present state of indifference will not continue indefinitely." The UCC engineer indicated a personal obligation to express this opinion to UCC managers out of concerns that the UCC engineering group might be held responsible if the proposed modifications were to result in poor performance. (A-2695).

42. **Final Design Basis for the Waste Disposal System:** A July 21, 1972 Memorandum entitled Waste Disposal for India SEVIN Unit, by UCC Chemicals and Plastics Engineering, South Charleston, West Virginia summarized the basis for final design of the waste treatment and disposal facilities (A-156). The report noted that "The Bhopal location presents an unusual challenge in that there is no nearby waterway into which the treated effluent can be discharged." The report acknowledged the evaluation was "… based on very preliminary and incomplete information and further study is recommended …". The report focused on the acid-bearing process wastes that were identified as clearly the major disposal problem for the proposed unit. The report also noted several potential problems that required resolution during the continuing design process. Among the follow up recommendations was a subsequent December 31, 1972 UCC CEC memorandum outlining a procedure for obtaining on-site evaporation rates. (A-156).

43. **Final Design Lead Responsibilities:** Subsequently, an undated document entitled Definition of Services And Plans for Process Liason For Technology Supplied by UCC (A-3127) UCC and UCIL developed a protocol to guide the interim and final design process, with the indicated purpose "… to record in detail the services supplied by UCC and complementary activities required by UCIL in order that the U.S. technology may be translated into a soundly designed plant in India."

44. The document was prefaced by the "NEED FOR SPECIAL DEFINITION OF RELATIONSHIPS" predicating the need for the particular division of design tasks on three key circumstances:
    i) acknowledgement that: "The processes being supplied by UCC are among the most sophisticated and exacting processes practiced by UCC – especially with regard to corrosivity and the handling of highly toxic materials."
    ii) acknowledgement that that limits on equipment and materials in India will undoubtedly require modifications of the U.S. design, and
    iii) that a shortage of U.S. engineering capacity requires that portions of the design normally performed by UCC will be delegated to India. (A-3127)

45. The document does not indicate which responsibilities normally retained in the U.S. engineering group were delegated to India due to the manpower shortage at UCC. However, it does delineate the lead design responsibilities for various elements of the project including that UCC will provide the Project Manager for the project, and that UCC was charged with the basic responsibility for the safety and operability of the plant design. UCC had lead responsibilities for all of the major processes producing wastes at the plant. UCC was responsible to provide UCIL with tabulations of the quantities of liquid and gaseous waste streams and their compositions. (A-3127, Munoz Affidavit 1985)

46. UCIL was assigned largely ancillary design responsibilities including receiving, storage, utilities, disposal of wastes, fire protection, etc. UCIL was assigned with the specific responsibility of maintaining the technical integrity of process designs supplied by UCC, "… with technical participation and approval of UCC engineers." (AC-3127).

47. Presumably, in part due to concerns over delegating normally U.S. engineering responsibilities to UCIL, strict limitations were placed on UCIL with regard to modifying or changing the designs to adapt to India conditions. UCIL was to:

> "Issue written change notices for any modifications that are made in the design. The purpose of the change notices will be a) to obtain the concurrence of U.S engineers and others in the changes and b) to maintain an orderly record of the design. … The United States engineer will be expected to provide prompt response to each change notice, either

indicating his approval or providing alternative recommendation."(A-3138)

48. These restrictions significantly curtailed UCIL's independence in modifying the preliminary design defined in the Definition of Scope and left complete primary or review authority to UCC. With regard to waste management, UCC delegated waste disposal to UCIL under this proviso. However, there are two important points to note in this regard: i) waste disposal is only one element of the overall waste management system. UCC retained lead design responsibility in the areas of waste generation, and ii) UCC subsequently reviewed and rejected UCIL proposed modifications to the waste disposal system, and undertook process and design modifications that modified the waste stream, so that UCCs waste disposal strategy remained feasible. UCIL was directed by the scope defined by UCC, and UCC retained and exercised the authority to reject and overrule UCIL proposed modifications.

49. **Benchmark Design Reports:** A June 15, 1973 UCC Memorandum indicates that some of UCC recommendations and requests for information were carried out in India and the results relayed to UCC Engineers in January, March and May of 1973 transmittals. The results of the evaporation tests requested by UCC in the UCC December 1972 Memorandum were relayed by UCIL in a May 1973 memorandum. The results indicated evaporation rates significantly lower than were anticipated in the basis for final design issued by UCC in July 1972. On review of the data UCC concluded that the evaporation rates in Bhopal were only 35% of that assumed by UCC in the preliminary design reports. An error of this magnitude undoubtedly caused considerable concern regarding the viability of the basic waste treatment strategy and design of the system. The January UCIL technical memorandum proposed major modifications to the design of the overall waste treatment system including the addition of sulfuric acid recovery system, relaxation of the main design criteria requiring that the SEP be sized to accommodate the full hydraulic load, and the addition of re-circulation pumps and spray nozzles to mist the effluent over the pond surface to enhance evaporation in the dry season. (A-2714)

50. In the June 15, 1973 memorandum, UCC noted a discrepancy between the July 21, 1972 basis of final design concept and the January 2, 1973 UCIL proposed design. The basis of final design report required that the surface evaporation balance the total water inflow from the plant plus rainfall. The January design report, however, indicated selection of pond incapable of handling the waste flows without an accumulation of water and a life expectancy of nine-months. UCC review engineers indicated that this was a different philosophy with regard to waste treatment and management than that indicated in the basis of design documents; and indicated that the proposed design was not advisable. UCC went on to provide pond sizing calculations indicating that, by coincidence, the waste flows following addition of the sulfuric acid absorption system were also 35% of original calculation. As a result, the error in the assumed evaporation rates was

off-set by the proposed process modifications, requiring no change in the original pond size of approximately 35 acres recommended by UCC in the basis of design document. (A-2714)

51. A December 1973 design summary report notes the waste disposal strategy remained the same as proposed by UCC two years earlier and had received provisional approval from the Indian regulatory authority, although acknowledging that: "At present, there are no State or Central Government laws and/or regulations for environmental protection." (A-116.)

52. The report goes on to note several of the processes have not been tried commercially, and "… even the MIC-to-Sevin process as developed by UCC, has had only a limited trial run. Furthermore, while similar waste streams have been handled elsewhere, this particular combination of materials to be disposed of is new and, accordingly, affords chance for difficulty. In short it can be expected there will be interruptions in operations and delays in reaching capacity or product quality that might have been avoided by adoption of proven technology."(A-116).

53. The report further notes that UCC C&P is developing the design for those manufacturing units that constituted the major waste producers for the plant.

54. These reports indicate a UCC continued to play a substantial and influential role in the waste treatment design process. However, it had become clear that UCC's error in the assumed evaporation rates used in the basis of design reports threatened the viability of the neutralization/SEP disposal strategy.

55. A major review of the Project was conducted by UCC in February 1977. The document indicated that the project was authorized to proceed in December 1973 and construction of some units had commenced in 1974. The project was halted in the first quarter of 1976 due to disruptions in global markets, general economic conditions, and decline in the favorability of international projects. A significant re-evaluation of plant economics was undertaken. The potential profitability of the India operations was significantly diminished and UCC considered abandoning the project. Numerous cost-saving and cost-cutting measures were applied in design to improve the potential profitability of the plant. UCC determined to continue with the project on the basis of its commitment to the Government of India. (A-1604).

56. With regard to the waste treatment system, the report indicates the intent of the system was to comply with the "Environmental Protection & Pollution Abatement" regulations currently in force in India" and UCIL is awaiting approval by the Pollution Board. However, the report indicates that UCC engineers investigated and implemented significant modifications within the product manufacturing processes to reduce the waste evaporation demand at the SEP and modifications to the SEP operations. The revised cost estimates show a substantial increase in capital expenditures and associated reductions in projected

operating costs for the waste treatment system. Review of the support information in the Appendices indicates that these cost reductions were achieved by reducing the amount of wastes produced through major modifications to the process unit designs provided by UCC. The document also forecasts utilizing 4 full-time UCC personnel in Bhopal for six months during the startup period.

57. **Final Design, Construction and Start-up:** Based on the improved plant economics, UCC determined to continue the project with a revised startup schedule. A document entitled the General Operating Manual dated February 1977 describes the waste treatment process at the plant in anticipation of the startup of operations. The document addresses overall operations of the entire plant. With regard to the waste management system, the various waste generating operations, waste streams and proper disposition of wastes produced throughout the facility are addressed. It is clear from the discussions and presentation that the waste management system encompasses the entire facility including the manufacturing process areas designed and provided by UCC. A particular effort is made to point out that the premiere consideration and first step in the waste management strategy is "to ensure sharp operating practices" that minimize the generation of waste by the industrial and manufacturing processes. The description is prefaced by the following comment:

> "General
>
> All organic chemical reactions invariably produce some undesirable products along with the desirable ones. These undesirable products come out of the process streams as waste. Waste streams are, therefore, normally generated from the manufacturing process and utility units. More than normal amounts of these wastes are produced during process upsets, failure of equipment, shut-down and start-up and during emergencies (e.g. utility failures, fires explosions, etc.).
>
> It is therefore imperative to ensure sharp operating practices to minimize the formation of unwanted wastes or degraded products and operate at peak efficiency.
>
> The wastes formed or generated cannot be discharged or dumped without proper treatment. Otherwise these will cause health and environmental problems. Proper treatment has therefore to be given prior to disposal of all wastes.
>
> In this chapter, we shall broadly outline the waste streams which are likely to come out of the various units together with the treatment facilities in the plant. It may be pointed out now that the waste disposal system can never be considered complete. Everyday new ways and means are being found out to cope with peculiar problems. Ours is a plant having many new features and is unique in many aspects. The most suitable waste disposal

system will have to be evolved after gaining the experience of plant operations." (A-228)

58. These admonitions indicate that there were substantial concerns with the modifications to and introduction of new processes, the resultant new waste streams, and technological risks inherent in the novel process designs noted in the 1973 Design Reports. Several of these modifications were, in large part, undertaken by UCC to reduce waste loads to salvage the viability of the neutralization/SEP waste management strategy. There was especial concern indicated with the potential effects of upsets, malfunctions, and startup/shutdowns that could exacerbate the waste management challenges. As a result, it is clear that UCC continued to have significant influence on the design of waste management facilities throughout the entire design and construction process, and provided experienced Institute plant personnel to Bhopal for the first six months of operations to help mitigate those concerns. (A-116, Munoz Affidavit 1985).

59. The plant initiated operations in 1977 and the waste disposal system and SEP operated through 1984. There is substantial evidence of failure of the waste disposal system, including leakage and releases of contaminants from the SEP. There is also evidence that these waste materials remain on site today and continue to pose a risk to public health. (Johnson et al. 2009; Burmeier et al. 2005)

60. Contemporaneous with these activities, the U.S. Environmental Protection Agency, National Enforcement Investigations Center conducted an intensive compliance and wastewater characterization survey over several months in 1977-78 at the Institute, West Virginia plant. Although, the Institute plant produced several chemical products in addition to those at Bhopal, the report indicates that Sevin (the primary product at Bhopal) was also the largest product at Institute. The design of the Bhopal facilities was based on the Institute plant and experience. The report contains detailed descriptions of the processes, pollution sources, wastes, treatment facilities, waste water characteristics, and compliance with discharge permit requirements. (USEPA_NEIC 1979)

61. The report found that the UCC Institute plant's self-reported discharge monitoring reports indicated the plant's main discharge outfall from the waste water treatment plant was out of compliance the majority of months between October 1977 and March 1978 analyzed in the study. The report also indicates that the Sevin processes are highly corrosive resulting in an unusual number of leaks from condensers, pipes, pumps, etc. and the process area is diked to collect waste waters that are routed to the waste water treatment plant. (USEPA_NEIC 1979)

62. This report is important to consider, as it indicates significant problems at the Institute, West Virginia plant on which the Bhopal design was based. The Institute plant was based on proven technology, had been operating for some time, and discharged wastes to a large waste treatment facility and adjacent river. Despite

years of experience utilizing established technologies, and the capacity to discharge process wastes to an integrated waste water treatment plant capable of storing, diluting, treating and clarifying routine and atypical waste loads, the Institute plant failed to meet is discharge permit limitations the majority of the time. (USEPA NEIC 1979).

63. UCC advanced these same technologies as the basis for design of the Bhopal facility, with substantially less waste treatment capacity and resiliency. This strategy was based on admittedly very preliminary and uncertain assumptions that proved to be grossly in error. In order to salvage the waste treatment strategy and ultimately the Bhopal site, which was already under construction, major modifications in UCC processes were adopted to reduce waste loads. These modifications amplified the already high level of uncertainty and unreliability of the waste load and discharge characteristics. UCC was responsible to provide accurate estimates of the waste volumes and compositions to UCIL to appropriately size the neutralization / SEP system. There is no evidence suggesting that UCC provided estimates of the potential magnitude and composition of atypical waste loads the system would need to accommodate.

64. In summary, from a waste management perspective, UCC undertook a high risk approach in siting the plant with the proposed neutralization/SEP facility at the Bhopal site. In comparison to the Institute plant on which the Bhopal design was based, the site and proposed waste management strategy lacked both the resiliency of a treatment plant to accommodate varying waste loads, and the river to accept the neutralized salt discharges. In addition, UCC was aware that the U.S. Institute plant frequently failed to meet its pollution discharge requirements, even with the level of redundancy and margin of safety inherent in the design of the Institute, West Virginia plant . The lack of resiliency and flexibility in the Bhopal design significantly increased the likelihood of releases of pollutants to the environment, had the strategy been viable.

65. However, the waste management system specified in the basis of final design was not viable. UCC's waste management strategy was based on faulty meteorological assumptions that proved grossly in error, rendering the site unsuitable for the original strategy, thus requiring substantial revisions to the basis of final design. Those modifications, for the most part, occurred in UCC's design of manufacturing processes to reduce waste loads. Those process modifications, self-admittedly, exacerbated the technology risks and the likelihood of upsets and malfunctions. The treatment/disposal elements of waste management system were ill-prepared to accommodate these excursions. The potential design risk for failure and consequent contamination of the local environment was considerably greater with respect to UCC's manufacturing process design modifications than to the design of the SEP, which was forced to accommodate the excursions in the waste generation. In addition, the SEP sizing design was wholly dependent on UCC's waste load projections.

66. UCC's high-risk overall waste management strategy ultimately resulted in inadequate waste management system performance that has left a legacy of soil and groundwater contamination posing a continuing threat to the environment and human health in Bhopal.

67. I reserve the right to modify my opinion upon review of additional information.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed on January 17, 2014 at Moscow, Idaho

[signature]

Ian H. von Lindern

On this 17 day of January, 2014; before me, the undersigned, a Notary Public in said Latah County, Idaho, personally appeared Ian H. von Lindern, known to me to be the person whose name is subscribed to the foregoing instrument, and acknowledged that he executed the same.

In witness whereof, I have hereunto set my hand and affixed my official seal, the day, and year first written above.

[signature] Lorie L. Eggers

Notary Public in and for the
State of Idaho, residing at Moscow therein

My Commission expires on: 3/23/15

LORIE L. EGGERS
NOTARY PUBLIC
STATE OF IDAHO

Material Reviewed

My review incorporates the material reviewed in my previous affidavit in this case and the following:

USEPA NEIC 1979, Compliance Evaluation and Waste Water Characterization, Union Carbide Company, Institute, West Virginia. United States Environmental Protection Agency, Office of Enforcement, EPA 330/2-79-014a, May 1979.

UCC 04514

Proposal by Union Carbide – India Limited to manufacture technical Sevin and Temik 10 G insecticides in Bhopal, India, dated December 2, 1973 (A105-A148)

Outline entitled, "Rationale for EIA ratings on the MIC bases pesticide unit to be located at Bhopal, India (A152-A153)

Transmittal memorandum attaching memorandum from UCC engineering regarding waste disposal for India Sevin unit, dated July 21, 1972 (A155-A162)

Excerpts from General Operating Manual, Bhopal Pesticides Plant, dated February 1977 (A227-A232)

Union Carbide India Limited, Review of CBP: 73-8 Methyl Isocyanate based agricultural chemicals project (A1604-A1653)

Record Memorandum, dated May 9, 1972 (A2695-A2696)

Memorandum from UCC to UCIL re: India Sevin project – input on waste disposal, dated June 13, 1973 (A2713)

UCC Memo from G. R. Hattiangadi, dated June 15, 1973 (A2714-A2716)

Waste disposal summary chart of Sevin Project in Bhopal India (A2722-A2725)

Waste disposal summary chart of Sevin Project in Bhopal India (A2737-A2750)

Correspondence from UCIL to Mr. Bhide re: pond, dated December 17, 1982 (A2759)

UCIL MIC-based Pesticides Projects, Bhopal: Waste disposal system definition of facilities report, dated February 7, 1976 (A2879-A2922)

India "Sevin" Project: Definition of services and plans for continuing process liaison for technology supplied by UCC, dated July 12, 1973 (A3127-A3139)

Correspondence from A. W. Byer to L. J. Couvaras re: Sevin Project – India HCL disposal, dated May 5, 1972 (UCC 04514-4515)

Affidavit of Edward Munoz, dated January 24, 1985

S. Johnson, R. Sahu, N. Jadon, C. Duca, 2009, "Contamination of soil and water inside and outside the Union Carbide India Limited, Bhopal," Centre for Science and Environment, New Delhi, India, December 2009.

H. Burmeier, J. Exner, F. Schenker, 2005, "Technical Assessment of Remediation Technologies for the Cleanup of the Former Union Carbide Site in Bhopal, India," April.

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http://www.studentsforbhopal.org/Bhopal.WaterContaminants.pdf

"Union Carbide Factory in Bhopal: Still a potential Killer." (2001)
http://www.bhopal.net/oldsite/contamination.html

Labunska, I. and D. Santillo (2004). High levels of chlorinated organic compounds, including tetrachloromethane, in water from well adjacent to former Union Carbide India Ltd (UCIL) pesticide plant, Bhopal (India), Greenpeace Research Laboratories.

Dhara, v.R. (2002). "The Union Carbide Disaster in Bhopal: A Review of Health Effects." Archives of Environmental Health. 57(5):391-404.

Stringer, R. and P. Johnston (2002). Technical guidelines for cleanup at the Union Carbide India Ltd (UCIL) site in Bhopal, Madya Pradesh, India. Greenpeace Laboratories

Dhara, V.R. (2002). "Bhopal Disaster Investigation." Int J Occup Environ Health. 8(4): 371-379.

Cullinan. P., Acquilla. S., et al. (1997). "Respiratory morbidity 10 years after the Union Carbide gas leak at Bhopal: a cross-sectional survey." BMJ. 314:338-42.

Dhara. V.R. et al, (2002). "Personal Exposure and Long-Term Health Effects in Survivors of the Union Carbide Disaster at Bhopal" Environmental Health Perspectives. 10(5):487-499.

Kumari, B. and T.S. Kathpal (1995). "Level of contamination of milk with HCH and DDT in Haryana." Indian Journal of Animal Science 65(5): 576-582.

Nair, A.et al. (1996). "DDT and HCH load in mothers and their infants in Delhi, India." Bulletin of Environmental Contamination and Toxicology. 56(1) : 58-64 .
Mercury Pollution in India (pages 14-17)
http://www.chem.unep.ch/mercury/2003-gov-sub/India-submission.pdf

Karanth, N.G.K. (2000). Challenges of Limiting Pesticide Residues in Fresh Vegetables:

The Indian Experience. Mysore, Central Food Technological Research Institute.

Surviving Bhopal 2002 Toxic present-Toxic Future. (2002)
A Report on Human and Environmental Chemical Contamination around the Bhopal disaster site, SRISHTI, Fact Finding Mission on Bhopal.

Dikshith. T.S.S. et al, (1990). "Residues of DDT and HCH in Major Sources of Drinking Water in Bhopal, India." Bull. Environ. Contam. Toxicol. 45:389-393.

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http://textonly.mde.state.md.us/assets/document/hazcleanup_Aug2001.pdf
http://www.who.int/en/
http://www.who.int/water_sanitation_health/dwq/en/gdwq3_12.pdf
Toxicological data, PRGs, RfDs and SFs:
http://www.epa.gov/iris/subst/index.html
http://www.epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf
http://www.atsdr.cdc.gov/toxpro2.html
http://www.atsdr.cdc.gov/mrls.html
http://www.atsdr.cdc.gov/iphome.html
EPA sampling

TerraGraphics
Environmental Engineering, Inc.

Ian H. von Lindern, P.E.

Chief Executive Officer/Senior Scientist

Education

Ph.D., Environmental Science and Engineering
Yale University, 1980

M.S., Biometeorology and Atmospheric Studies
Yale University, 1973

B.S., Chemical Engineering
Carnegie-Mellon University, 1971

Professional & Technical Certifications

Professional Engineer
Idaho # 3044 ChE (1975)

Experience Summary

Ian von Lindern has been Chief Executive Officer and principal scientist of TerraGraphics Environmental Engineering since co-founding the firm in 1984. Dr. von Lindern has almost 40 years of national and international environmental engineering/science experience that includes a variety of environmental assessments; special studies in air, water, and soil pollution; toxic and hazardous materials investigations; remedial and cleanup plans; human health risk assessments; litigation assistance; and application of sophisticated statistical analysis techniques to multi-disciplinary environmental problems. Under his direction, TerraGraphics has developed into a multidisciplinary environmental firm, specializing in the design and management of complex projects including site characterization, risk assessment, hazardous waste remediation, engineering design, GIS and database, and remediation oversight.

Areas of Expertise

- Childhood Lead Poisoning
- Human Health Risk Assessment
- Environmental Assessments
- Litigation Assistance
- Hazardous Materials
- Site Characterization
- Project Management
- Remedial and Cleanup Plans
- Air, Water, Soil Pollution

Project Experience

Bunker Hill Mining and Metallurgical Complex/Coeur d'Alene Basin Superfund Site, Idaho, 1974–Present

Dr. von Lindern has worked for the State of Idaho on various projects involving the Bunker Hill/Coeur d'Alene Basin Superfund Site for more than 35 years, both as the lead Risk Assessor and as TerraGraphics' Project Manager for the State of Idaho CERCLA activities. In 1974, as an Environmental Engineer for the State of Idaho, he directed the field study of lead intoxication in children surrounding the Bunker Hill smelter. As State oversight contractor, his duties have included initial contact with local leaders, assisting IDEQ in Cooperative Agreement and PRP negotiations, legislative committee presentations, moderating Task Force meetings, reviewing PRP and EPA activities, and developing the risk management strategy and site-specific cleanup criteria. He also represented the State of Idaho IDEQ at National Academy of Sciences (NAS) review of this Project in Washington D.C. ***Superfund and Mining Megasites – Lessons Learned from the Coeur d'Alene River Basin,*** **(NRC 2005)**.

Dr. von Lindern led the completion of a comprehensive Human Health Risk Assessment (HHRA) of potential exposures and risks for the Coeur d'Alene Basin under a Memorandum of Agreement between the State of Idaho and the U.S. Environmental Protection Agency (U.S. EPA) Region 10. The project integrated existing data from State and federal health and exposure surveys, the Remedial Investigation/Feasibility Study (RI/FS) process, and the Natural Resource Damage Assessment ongoing in the Basin. Dr. von Lindern performed the lead risk portion of the HHRA while the EPA RAC contractor performed the non-lead risk portion of the HHRA. He has a number of peer-reviewed publications on the reduction of childhood blood lead levels and remedial activities at this site. He collaborated closely with IDEQ and the Panhandle Health District for the development and ongoing administration of the site-wide Institutional Controls Program (ICP).

TerraGraphics conducted site-specific quantitative analysis of the relationship between observed blood lead levels and environmental variables, and one of the most extensive evaluations of lead paint as an additional source of exposure at a CERCLA site. Blood lead data relative to yard and house dust lead levels have been analyzed to evaluate the effectiveness of the yard remediation program. Coeur d'Alene Tribe Subsistence Scenarios were also assessed in association with tribal representatives. These scenarios pertain to children and adults engaged in traditional (aboriginal) or current subsistence lifestyles in the floodplain of the Coeur d'Alene River.

Major Project Experience

Dr. von Lindern has directed over 40 major health/environmental projects including primary and secondary smelters, as well as battery processors, landfills, and uranium mill tailings at several major mining/smelting sites in the U.S. including: ASARCO/Tacoma, WA; East Helena and Butte/Anaconda, MT; and internationally in Canada, Peru, China, Russia, Senegal, Nigeria, Australia, and the Dominican Republic.

Bayhorse Mine Site Assessment & Remediation, Near Challis, Idaho, September 2006-Present

The Bayhorse Mine property is a well-known "ghost town" near Challis, Idaho with substantial historic value. After completion of an ASTM Phase I ESA and All Appropriate Inquiry standards, the IDPR was considering the site for development as a State of Idaho Park, and wanted to ensure the site was suitable for such use. Dr. von Lindern led the team that completed the assessment of human health risk and water quality concerns for the purchase of the Bayhorse Mine property. After the assessment, IDPR successfully acquired the Bayhorse Mine properties for converting the "ghost town" and associated abandoned mine holdings into a cultural, historical, and adventure recreation park.

To assist with evaluating risk, Dr. von Lindern led the collection of several hundred samples throughout the Townsite, associated mining operations, and 10 miles of trail system connecting the property parcels. A risk assessment using data from both X-ray fluorescence and wet chemistry analysis evaluated health risks from exposure to lead and arsenic. Concentrations of lead were as high as 214,000 ppm and arsenic concentrations were as high as 120,000 ppm.

Dr. von Lindern worked with IDEQ and IDPR from the initial investigations – Site suitability analysis, Phase I and II audits and property acquisition, site characterization, and risk assessment – to cleanup design and construction. Dr. von Lindern was involved with the designing the cleanup to protect human health, including the tailings pile closure, repository construction, slag grading, bridge and parking lot construction, and a trail system linking the townsite with the Upper Mines.

The Park design mimics innovative risk management strategies used at the Trail of the Coeur d'Alenes State Park in northern Idaho. Dr. von Lindern assisted IDEQ, IDPR, the U.S. EPA and other related agencies at both Parks by developing a risk management strategy that is protective of human health and the environment, while allowing public access and preserving the historic and recreational value of the resource. The Park opened to the public in June 2009. This project will finish after 2012 construction oversight and final documentation have been completed.

Washington State Department of Justice – Natural Resources Division Litigation Support and Expert Witness, Northeastern Washington State, December 2009–Present (completion: December 2012)

Dr von Lindern, a nationally and internationally recognized expert in exposure assessment for lead poisoning, has provided expert witness testimony and reports for numerous enforcement and civil environmental liability lawsuits and litigation at sites throughout the United States. He is Principal-in-Charge for a contract with the Washington State Attorney General Office, Natural Resources Division, regarding potential mining contamination in northeastern Washington state. He and other TerraGraphics personnel researched and visited numerous old mine sites and collected samples to assess metal contamination associated with abandoned mine sites. Dr. von Lindern provided his expert opinion to the client for litigation support.

International Environmental Health and Restoration Initiative, 2005–Present

Since 2005, Dr. von Lindern has continued his mission to eliminate childhood lead poisoning by starting and co-leading a joint Research & Development initiative between TerraGraphics and the University of Idaho. The objective of the initiative is to adopt and apply environmental cleanup methodologies developed in Idaho mining districts to hazardous waste sites in the developing world. He is accomplishing this objective by adapting those technologies to local cultural, economic, and socio-economic conditions. Projects are currently underway or completed in conjunction with local governments, universities, and NGOs in Nigeria, the Dominican Republic, Senegal, Russia, Peru and China.

Lead Poisoning - Emergency Health Response, Zamfara State, Northern Nigeria, May 2010–Present

Dr von Lindern was contacted by the Centers for Disease Control to provide his expertise for an international emergency health issue discovered by Médecins Sans Frontières. In 2010/2011, Dr von Lindern spent months on assignment in northern Nigeria directing the characterization and remediation of the world's worst lead poisoning epidemic. Hundreds of children and adults died and nearly two thousand children are under treatment by the international NGO Médecins Sans Frontières for lead poisoning in a number of villages where residents were mining for gold. Dr. von Lindern has been heading the environmental investigation and remediation efforts underway to create a living environment that does not continue to expose residents to the extremely high levels of lead. He and other TerraGraphics personnel worked cooperatively with local authorities, Médecins Sans Frontières, the Centers for Disease Control (CDC), the World Health Organization, the Blacksmith Institute, and government officials and villagers in remote areas to develop an emergency response and remove contaminated soils.

At CDC's request, TerraGraphics assisted with and provided equipment and expertise in confirming that lead poisoning had resulted in 163 deaths among children less than five years of age in two villages. The medical response was to provide oral chelation therapy for children five years of age and under. The efficacy of chelation therapy is compromised if medically treated children return to contaminated homes. This necessitated immediate remediation of the villages to secure clean environments for the children returning from treatment as well as to reduce lead exposure to older children and adults to whom chelation was not available. Contaminated soil was removed to secure landfills and replaced with clean soil. In total, seven villages were remediated, including 430 residential compounds, 107 exterior areas and 23 processing ponds. TerraGraphics trained more than 200 regional and local government, village, and private personnel to carry out the remediation, building Nigerian capacity to conduct future remediation activities.

In May 2011, TerraGraphics was recognized by the United Nations Environment Programme (UNEP) and Green Cross International with the Green Star Award, given to every two years in association with U.N. reviews of its environmental programs to recognize those who have made remarkable efforts to prevent, prepare for, and respond to environmental emergencies around the world.

Regulatory Knowledge

Ian von Lindern has worked on projects regulated under Federal, State, local, and foreign regulations, including CERCLA, TSCA, CWA, CAA, NESHAPs, DOT, EPRCRA, SARA, NEPA, and RCRA in the U.S. He has provided litigation support and expert witness testimony in administrative and court proceedings. He has served on several U.S. government advisory panels, including the appointments pertinent to lead health and remediation as shown in the list below..

Special Appointments/Memberships/Affiliations

- U.S. Centers for Disease Control and the Harvard University School of Public Health Initiative to address health effects of mining and smelting in the developing world. 2011-Present.
- Affiliate Professor of Chemical Engineering, University of Idaho, Moscow, Idaho, 1981–2011
- U.S. EPA Science Advisory Board. Review of the Lead National Ambient Air Quality Standard for Lead. U.S. EPA, Washington, DC. 2006-2008.
- U.S. Clean Air Scientific Advisory Committee (CASAC). Review of the Air Quality Criteria Document for Lead. U.S. EPA, Washington, DC. 2010-2013, 2006-2007.
- U.S. EPA Science Advisory Board. Review of EPA's Lead Renovation, Repair and Painting (LRRP) Activities. U.S. EPA, Washington, DC. 2007.
- U.S. EPA Science Advisory Board. Review of EPA's Ad Hoc All-Ages Lead Model (AALM) Review Panel. U.S. EPA, Washington, DC. 2007.
- U.S. EPA Science Advisory Board. Review Subcommittee for Urban Soil Lead Abatement Demonstration Project. U.S. EPA, Washington, DC, 1993-1995.
- NIEHS Select Reviewer Grants Review Committee, Superfund/Hazardous Workers Training Program, NIEHS, RTP, NC. 1992.
- Advisory Committee for Development of Lead Paint Abatement Guidelines for Public Housing in the United States, U.S. Dept of HUD, Washington, D.C., 1992.
- U.S. EPA Science Advisory Board, Subcommittee Assessing the Consistency of Lead Health Regulations in U.S. EPA Programs, Special Report to the Administrator, Washington, D.C., 1992.
- U.S. EPA Science Advisory Board, Review Subcommittee Assessing the Use of the Biokinetic Model for Lead Absorption in Children at RCRA/CERCLA sites. U.S. EPA, Washington DC, 1991.

- Technical advisor and consultant to Latah County and North Central Health District Regional Solid Waste Advisory Committees, Moscow and Lewiston, ID. 1991.
- Technical advisor to the National Alliance to End Lead Poisoning in Children, Washington, D.C. 1991-2001
- NIEHS Select Reviewer Grants Review Committee, Superfund/Hazardous Workers Training Program, NIEHS, Research Triangle Park, NC, 1989-1993.
- U.S. EPA Clean Air Scientific Advisory Committee (CASAC) Member, Subcommittee on Exposure Assessment Methodology, U.S. EPA, Washington D.C. 1988.
- Member U.S. EPA Criteria Assessment Committee for Lead in the Ambient Air, RTP, NC. 1975-1986.

Additional Certifications/Training

- PSMJ Conference for CEOs-2005

Selected Publications/Reports/Presentations

Artisanal Mining Lead Poisoning Epidemic, Zamfara State, Nigeria, 2010-11, Phase I and II Emergency Response Cleanup. *Prepared for:* Médecins Sans Frontières. *Prepared by:* TerraGraphics Environmental Engineering. October 2011.

Health Response to the World's Worst Lead Poisoning Epidemic - Zamfara, Nigeria 2010-11 prepared for the Zamfara Ministry of Environment, Gusau, Nigeria

The Life Cycle of Metals: Improving Health, Environment and Human Security, Symposium. University of Tokyo and Harvard University. Tokyo, Japan. October, 2011.

Cleanup Recommendations for Begaga Village, Zamfara State, Nigeria, 2010-2011. Prepared for: Médecins Sans Frontières (MSF). Prepared by: TerraGraphics Environmental Engineering. October 2011.

Artisanal Mining Lead Poisoning Epidemic, Zamfara State, Nigeria, 2010-2011. Assessment of Remedial Effectiveness - Phase I and II Emergency Response Cleanup *Summary Report Prepared for:* Médecins Sans Frontières. *Prepared by:* TerraGraphics Environmental Engineering. August 2011.

Health Response to the World's Worst Lead Poisoning Epidemic, Zamfara, Nigeria 2010-11 Presentation to U.S. Environmental Protection Agency Headquarters, International Programs. July, 2011

A Comprehensive Approach to Remediation of the Lead Poisoning Epidemic in Zamfara, Nigeria. Joint Presentation with Médecins Sans Frontières to the Ninth meeting of the Advisory Group on Environmental Emergencies (AGEE). United Nations Environment Program, Office of Coordination of Humanitarian Affairs. Bern, Switzerland, May 2011.

Lead Poisoning -The World's Worst are Becoming Worse. More Children at More Places are More Severely Poisoned. Presentation to the U.S. Centers for Disease Control, Lead Poisoning Program. Atlanta, Georgia, April 2011.

A Comprehensive Approach to Remediation of the Lead Poisoning Epidemic in Zamfara. Presentation to the Nigerian Public Health Association, Annual Conference. Abuja, Nigeria. March 2011.

Zamfara, Nigeria Lead Poisoning Epidemic Emergency Environmental Response. May 2010-March 2011. Final Report United Nations Children's Fund (UNICEF). Programme Cooperation Agreement YW-303(01). TerraGraphics Environmental Engineering, February, 2011.

Adapting U.S. Hazardous Waste Cleanup Protocols to International Mining and Smelting Sites. Consortium to Prevent and Mitigate the Environmental and Health Consequences of Metal Mining and Smelting. US Centers for Disease Control/Harvard School of Public Health. Symposium. Bozeman, Montana. May, 2010.

The Cost of Legacy Toxic Waste Sites. Consortium to Prevent and Mitigate the Environmental and Health Consequences of Metal Mining and Smelting. US Centers for Disease Control/Harvard School of Public Health. Symposium. Cambridge, Massachusetts. July, 2009

Comprehensive Health Response and Cleanup Strategy for the Lead-Acid Battery Recycling Community of Thiaroye Sur Mer, Dakar, Senegal. Prepared for the Senegalese Ministry of Environment, Dakar, Senegal. February 2009.

Site Visit Report and Recommendations, Doe Run Peru (DRP) Metallurgical Facility, La Oroya, Peru. International Environmental Health and Restoration Initiative, University of Idaho, Moscow, Idaho USA. May 2008.

Spalinger, S.M., von Braun, M.C., Petrosyan, V., von Lindern, I.H. Northern Idaho House Dust and Soil Lead Levels Compared to the Bunker Hill Superfund Site. Environ. Monit. Assess. 130: 57-72, 2007.

Comprehensive Health Response and Cleanup Strategy for the Former Metaloxa Lead-Acid Battery Recycling Site in Paraiso del Dios, Haina, Dominican Republic. Prepared for the Dominican Republic, Ministry of Environment. October 2007.

Petrosyan, V., von Braun, M.C., Spalinger, S.M, von Lindern, IH. Seasonal variations of lead concentration and loading rates in residential house dust in northern Idaho. Journal of Hazardous Materials 132: 68-79, 2006.

Comprehensive Health Response and Cleanup Strategy for the Rudnaya Pristan Site in Far East Russia. Prepared for the Far East Health Fund. Vladivostok, Primorye, Russia. November 2006.

von Lindern, I.H., S.M. Spalinger, B.N. Bero, V. Petrosyan, M.C. von Braun, "The influence of soil remediation on lead in house dust," *Science of the Total Environment*, Vol. 303/1-2, pp. 59-78, 2003

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von Braun, M.C., I. von Lindern, N.K. Khristoforova, A.H. Kachur, P.V. Yelpatyevsky, P.V. Elpatyevskaya, S.M. Spalinger, "Environmental Lead Contamination in the Rudnaya-Pristan Dalnegorsk Mining and Smelter District, Russian Far East," Environmental Research, 88, 164-173, 2002.

Bero, B., M.C. von Braun, I. von Lindern, J.E. Hammel, and R. Korus, "Evaluation of six vacuum techniques for sampling lead contaminated carpeted surfaces," Advances in Environmental Research, Vol. 1, No. 3, pp. 333-344. 1998.

Assessment of Historical Lead Exposures in the Port Richmond Area of Philadelphia. Prepared for Counsel in Wagner vs. Anzon and N.L. Industries. August 1993.

An Evaluation of Institutional Controls for the Populated Areas of Bunker Hill Superfund Site. Prepared for Panhandle Health District. January 25, 1991.

Use of a Geographic Information System in Selecting Residential Properties for Remediation at the Bunker Hill National Priorities List Site. Proceedings of the 10th National Conference on Management of Uncontrolled Hazardous Waste Sites, Superfund, Washington, D.C. Co-authored by Kara Steward and Margrit von Braun of TerraGraphics, and by Sally Martyn of US Environmental Protection Agency, Region X. November 1989.

Reconstructive Analysis of Lead Exposures in a Smelter Community Using Geographic Information System Techniques. Proceedings of Society for Occupational and Environmental Health Conference, Washington D.C. Co-authored by Margrit von Braun. April 1988.

A Modeling Technique to Evaluate Community and Occupational Airborne Lead Exposure In and Around a Primary Lead Smelter. Prepared for the National Institute of Occupational Safety and Health, R.A. Taft Laboratory, Cincinnati, Ohio. June 30, 1982.

Age-Specific Risk Factors for Lead Absorption in Children. Archives of Environmental Health. Vol. 35, no. 1. January/February 1980.

The Silver Valley Lead Study: The Relationship Between Childhood Blood Lead Levels and Environmental Exposure. Journal of Air Pollution Contamination Association. Vol. 27, No. 8. August 1977.