것으로서, 주의를 기울여야 한다.

5-V-3. 복합경로에 의한 Risk

여러 경로에 의해 노출되었을 경우의 위해도 평가는 carcinogen의 경우 각 exposure pathway에 의한 risk 값을 산술합산하여 아래와 같이 계산하며

Cancer Risk Equation for Multiple Pathways

Total Exposure Cancer Risk =
Risk (Exposure pathway$_1$) +
Risk (Exposure pathway$_2$) + ···+
Risk (Exposure pathway$_i$)

또한 noncarcinogen도 각 exposure pathway 에 의한 Hazard Index값을 산술합산하여 다음과 같이 계산할 수 있다.

Hazard Index Equation for Multiple Pathways

Total Exposure Hazard Index =

Hazard index (Exposure pathway$_1$) +
Hazard index (Exposure pathway$_2$) + ···+
Hazard index (Exposure pathway$_i$)

Total Exposure Hazard Index is calculated separately for chronic, subchronic, and shorter-term exposure periods.

6. 맺음말

Risk Characterzation은 hazardous waste site의 현재와 앞으로 사용할 용도에 따라 발암성, 비발암성 위해 물질 노출에 대한 위해도를 결정하는 것이다. 즉 baseline risk assessment 는 그 장소를 환경적 차원에서 재생 (remediation) 할 것인지를 결정하는 것은 아니며 이와같은 결정을 하는 것은 Risk Management에서의 일이라 할 수 있다. 발암물질에 관해 이와같은 Risk Management 결정을 원활히 하기 위해 National Contingency Plan에서는 guideline을 제시하고 있기도 하다.

실제 우리나라에서 Risk Assessment는 국내의 경제성장과 더불어 환경문제에 관한 국민적 관심이 고조됨에 따라, 최근에 들어와서 독성학자들이 관심을 갖기 시작한 분야라 할 수 있다. 특히 Risk Assessment, Characterization, Management는 이제 막 국내에서 관심을 갖고 시작하는 단계로서 국내 전문가는 거의 전무한 실정이며, 이와 같은 일을 원활히 수행하기 위하여는 Risk Assessor, Risk Assessment Reviewer, Remedial Project

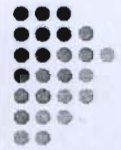
Manager (RPM), Risk Manager 등의 역할 분담은 물론 약학, 의학, 생물학, 화학, 통계학 등등의 자연과학과 인문과학이 망라되어 독성학의 어느 일정 수준을 갖고 있는 학자들의 적극적인 참여와, 정부가 중심이 된 환경에 관한 깊이 있고 일관성 있는 정책제시, 그리고 자연환경에 관한 철학, 전 국민적인 관심과 사랑이 합쳐져야만 우리 인간의 모태와도 같은 자연 환경 속에서 인류가 자연과 공존하며 정신적으로도 풍요로운 행복을 누릴 수 있으리라 사료된다.

7. 참고 문헌

1. Risk Assessment, Guidance for Superfund Vol. 1. Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002, US. EPA, 1989
2. Support Document for the CERCLA 104 Priority List of Hazardous Substances that will be the Subject of Toxicological Profiles, US. Public Health Service, 1992
3. Superfund Public Health Evaluation Manual, EPA/540/1-86/060, US.EPA, 1986
4. Superfund Exposure Assessment Manual, EPA/540/1-88/001, US.EPA, 1988
5. Field Test of the Proposed Revised Hazard Ranking System (HRS), EPA/540/P-90/001, US. EPA, 1990
6. L. B. Lave; Quantitative Risk Assessment in Regulation, The Brookings Institution, Washington, D.C., 1982
7. Environmental Risk Assessment Guidelines, Environment & Policy Institute, East-West Center, Honolulu, Hawaii, USA, 1990
8. Pesticide Usage Gudelines, EPA/600/M-91/035, US. EPA 1992
9. Application of a Water Quality Assessment Modeling System at a Superfund Site, EPA/600/3-91/046, US. EPA, 1991
10. Risk Assessment, Guidance for Superfund Vol. II, Environmental Evaluation Manual, Interim Final, EPA/540/1-89/001, 1989
11. E.J. Calabrese and E. M. Kenyon; Air Toxics and Risk Assessment, Lewis Publishers, 1991
12. L.G. Cockerham and B.S. Shane; Basic Environmental Toxicology, CRC Press, 1994
13. Hazard Ranking System Guidance Manual, EPA 540-R-92-026, US. EPA 1992
14. W. H. Hallenbeck and K.M. Cunningham; Quantitative Risk Assessment for Environmental and Occupational Health, Lewis Publishers Inc., 1988
15. Toxicological Risk Assessment Vol. I, Biological and Statistical Criteria, CRC Press, 1985

16. Toxicological Risk Assessment Vol. II, General Criteria and Case Studies, CRC Press, 1985
17. Risk and Reason; Risk Assessment in relation to Environmental Mutagens and Carcinogens, Alan R. Liss, Inc., 1985
18. Field Sampling Methods for Remedial Investigations, CRC Press, 1994
19. Genetic Risk Assessment : Parallelograms and Pragmatism, CIIT, 14(9), 1994
20. Toward an Improved Information Resource for Risk Assessment : EPA's Integrated Risk Information System (IRIS), CIIT, 14(10), 1994
21. Applications of Mechanistic Data in Toxicology/Risk Assessment, CIIT, 14(11), 1994
22. US EPA Reassessment of the Health Risks of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD), CIIT, 14(12), 1994
23. OECD Guidelines for the Testing of Chemicals, Vol. I & II, OECD, Paris, 1993

OECD GUIDELINES FOR TESTING OF CHEMICALS (1)



- SECTION 1 - PHYSICAL-CHEMICAL PROPERTIES (blue pages)
- Summary of Considerations in the Report from the OECD Expert Group on Physical Chemistry

- 101 UV-VIS Absorption Spectra(1)
- 102 Melting Point / Melting Range(1)
- 103 Boiling Point / Boiling Range(1)
- 104 Vapour Pressure Curve(1)
- 105 Water Solubility(1)
- 106 Absorption / Desorption(1)
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- 110 Particle Size Distribution / Fibre Length and Diameter Distributions(1)
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- 113 Screening Test for Thermal Stability and Stability in Air(1)
- 114 Viscosity of Liquids(1)
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- 116 Fat Solubility of Solid and Liquid Substances(1)
- 117 Partition Coefficient (n-octanol / water), HPLC Method(8)

OECD GUIDELINES FOR TESTING OF CHEMICALS (2)

- SECTION 2- EFFECTS ON BIOTIC SYSTEMS (green pages)
- Summary of Consideration in the Report from the OECD Expert Group on Ecotoxicology

- 201 Alga, Growth Inhibition Test(5)
- 202 *Daphnia* sp. Acute Immobilisation Test and Reproduction Test(3)
- 203 Fish, Acute Toxicity Test(9)
- 204 Fish, Prolonged Toxicity Test: 14-Day Study(4)
- 205 Avian Dietary Toxicity Test(4)
- 206 Avian Reproduction Test(4)
- 207 Earthworm, Acute Toxicity Tests(4)
- 208 Terrestrial Plants, Growth Test(4)
- 209 Activated Sludge, Respiration Inhibition Test(4)
- 210 Fish, Early-Life Stage Toxicity Test(10)

OECD GUIDELINES FOR TESTING OF CHEMICALS (3)

- SECTION 3- DEGRADATION AND ACCUMULATION (yellow pages)
- Summary of Considerations in the Report from the OECD Expert Group on Degradation / Accumulation

  - 301 Ready Biodegradability(9)
  - 301 A: DOC Die-Away Test
  - 301 B: CO_2 Evolution Test
  - 301 C: Modified MITI Test (I)
  - 301 D: Closed Bottle Test
  - 301 E: Modified OECD Screening Test
  - 301 F: Manometric Respirometry Test
  - 302 A Inherent Biodegradability: Modified SCAS Test(1)
  - 302 B Inherent Biodegradability: Zahn-Wellens / EMPA Test(9)
  - 302 C Inherent Biodegradability: Modified MITI Test (II)(1)
  - 303 A Simulation Test - Aerobic Sewage Treatment: Coupled Units Test(1)
  - 304 A Inherent Biodegradability in Soil(1)
  - 305 A Bioaccumulation: Sequential Static Fish Test(1)
  - 305 B Bioaccumulation: Semi-Static Fish Test(1)
  - 305 C Bioaccumulation: Degree of Bioconcentration in Fish(1)
  - 305 D Static Fish Test(1)
  - 305 E Flow-Through Fish Test(1)
  - 306 Biodegradability in Seawater(10)

OECD GUIDELINES FOR TESTING OF CHEMICALS (4-1)

- SECTION 4- HEALTH EFFECTS (pink pages)

  - 401 Acute Oral toxicity(7)
  - 402 Acute Dermal toxicity(7)
  - 403 Acute Inhalation toxicity(1)
  - 404 Acute Dermal Irritation / Corrosion(9)
  - 405 Acute Eye Irritation / Corrosion(7)
  - 406 Skin Sensitisation(9)
  - 407 Repeated Dose Oral Toxicity - Rodent: 28 / 14-Day(1)
  - 408 Subchronic Oral Toxicity - Rodent: 90-Day(1)
  - 409 Subchronic Oral Toxicity - Non-Rodent: 90-Day(1)
  - 410 Repeated Dose Dermal Toxicity: 21 / 28-Day(1)
  - 411 Subchronic Dermal Toxicity: 90-Day(1)
  - 412 Repeated Dose Inhalation Toxicity: 28 / 14-Day(1)
  - 413 Subchronic Inhalation Toxicity: 90-Day(1)
  - 414 Teratogenicity(1)
  - 415 One-Generation Reproduction Toxicity(2)
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  - 420 Acute Oral toxicity - Fixed Dose Method(10)

OECD GUIDELINES FOR TESTING OF CHEMICALS (4-2)

- SECTION 4- HEALTH EFFECTS (pink pages)
  - 451 Carcinogenicity Studies(1)
  - 452 Chronic Toxicity Studies(1)
  - 453 Combined Chronic Toxicity / Carcinogenicity Studies(1)
  - 471 Genetic Toxicology: *Salmonella typhimurium*, Reverse Mutation Assay(2)
  - 472 Genetic Toxicology: *Escherichia coli*, Reverse Mutation Assay(2)
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  - 474 Genetic Toxicology: Micronucleus Test(2)
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  - 476 Genetic Toxicology: *In vitro* Mammalian Cell Gene Mutation Tests(4)
  - 477 Genetic Toxicology: Sex-Linked Recessive Lethal Test in *Drosophila melanogaster*(4)
  - 478 Genetic Toxicology: Rodent Dominant Lethal Test(4)
  - 479 Genetic Toxicology: *In vitro* Sister Chromatid Exchange Assay in Mammalian Cells(6)
  - 480 Genetic Toxicology: *Saccharomyces cerevisiae*, Gene Mutation Assay(6)
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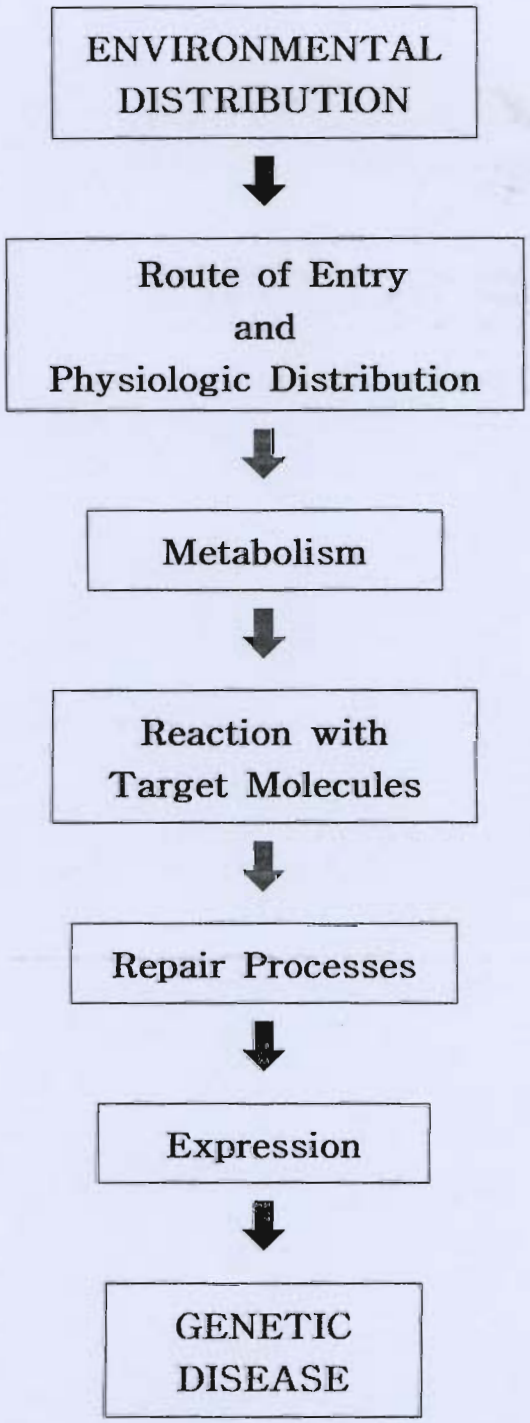
  - 482 Genetic Toxicology: DNA Damage and Repair, Unscheduled DNA Synthesis in Mammalian Cells *In vitro*(6)
  - 483 Genetic Toxicology: Mammalian Germ Cell Cytogenetic Assay(6)
  - 484 Genetic Toxicology: Mouse Spot Test(6)
  - 485 Genetic Toxicology: Mouse Heritable Translocation Assay(6)

Toxicologic Paradigm



Chemicals and Mixtures judged to be Carcinogenic to Humans by the International Agency for Research on Cancer

DNA-Reactive

Aflatoxins
4-Aminobiphenyl
2-Aminonaphthalene
5-Azacytidine
Benzidine
Betel quid with tabacco
N,N-bis(2-Chloroethyl)-2-aminonaphthalene
bis(Chloromethyl)ether
1,4-Butanediol dimethanesulfonate (Myleran)
Chlorambucil
1-(2-Chloroethyl)ether methylcyclohexyl)-1-nitrosourea
Chromium compounds, **hexavalent**
Coal tars
Cyclophosphamide
Melphalan
MOPP (**nitrogen mustard**, vincristine, procarbazine and prednisone)
Nickel and nickel compounds
Phenacetin-containing analgesic mixtures
Soot
Sulfur mustard
Triethylenethiophosphoramide (thiotepa)
Tabacco smoke and products
Treosulphan
Vinyl chloride

Epigenetic

Azathioprine
Cyclosporin A
Diethylstilbestrol
Estrogen, steroidal
Oral contraceptives

Unclassified

Alcoholic beverages
Arsenic and arsenic compounds
Benzene
Mineral oils, untreated and mildly treted
Shale oils

Data from International Agency for Research on Cancer(1987). The table does not include processes or fibers.

SOME FACTORS CONSIDERED IN ESTABLISHING ACCEPTABLE RISK LEVELS

Beneficial Aspects of the Chemical

Economic growth
Employment
Increased standard of living
Increased quality of life
Taxes generated

Detrimental Aspects of the Chemicals

Decreased quality of life
Emotional difficulties
Health effects
Lawsuits
Loss of environmental resources
Loss of work
Medical payments

ESTIMATED LIFETIME RISKS FROM VARIOUS SOURCES*

CAUSE OF DEATH	LIFETIME RISK
Measles	1.5×10^{-6}
Smallpox vaccination	5.0×10^{-6}
Lightning	3.0×10^{-5}
Electrocution	3.0×10^{-4}
Drowning	2.5×10^{-3}
Falls	6.0×10^{-3}
Motor vehicle	1.5×10^{-2}

* These statistical estimates are based on actuarial data and thus represent best estimates of risk, rather than "upper bounds" on risk. Lifetime risk estimates are derived by multiplying annual death by 70 years, then dividing by the total U.S. population

Carcinogens in Processed Natural Products

Important types of carcinogens, accounting for substantial portions of human cancers in many parts of the world, stem from the traditional use of specific processed natural products. Their genotoxicity, in most instances has been documented, as has their carcinogenicity, or cocarcinogenicity (alcohol).

PRODUCT	CARCINOGEN TYPE / METABOLITE
Tabacco, snuff	Nicotine alkaloid-derived nitrosamines
Pickled/smoked food	Nitosoindoles, phenol, diazotates
Cooked foods	Heterocyclic aromatic amines
Alcoholic beverages	Acetaldehyde

Carcinogens produced in Nature

A wide variety of toxic and carcinogenic chemicals occur in nature. Human exposure to these chemicals is probably greater than to synthetic carcinogens, and may be causes of several types of cancer. In animals some are carcinogens, others are promoters.

MICROORGANISMS	CLASSIFI-CATION	PLANTS	CLASSIFI-CATION
Actinomycins	D	Agaratine	D
Aflatoxins	D	Alpysiatoxin	E
Adriamycin	D	Aristolochic acid	U
Azaserine	D	β-Asarone (calamus oil)	U
Daunomycin	D	Betel nut	D
Elaiomycin	U	Bracken fern (ptaquiloside)	D
Ethionine	U	Cycasin	D
Griseofulvin	E	Coltsfoot	U
Islanditoxin	U	Debromoaplysiatoxin	E
Luteoskyrin	U	Gyromitrin	E
Mitomycin C	D	Okadaic acid	E
4-(Methylnitosamino) -1-(3-pyridyl-1-butanone	D	Phorbol esters	E
Nitorsonornicotine	D	Pyrrolizidine(Senecio) alkaloids	D
Ochratoxin A	D	Safrole	D
Sterigmatocystin	D	Teleocidin A and B	E
Streptozotocin	D	Thiourea, goitrogens	E

D = DNA-reactive ; E = Epigenetic ; U = Unclassified