Exposure Assessment

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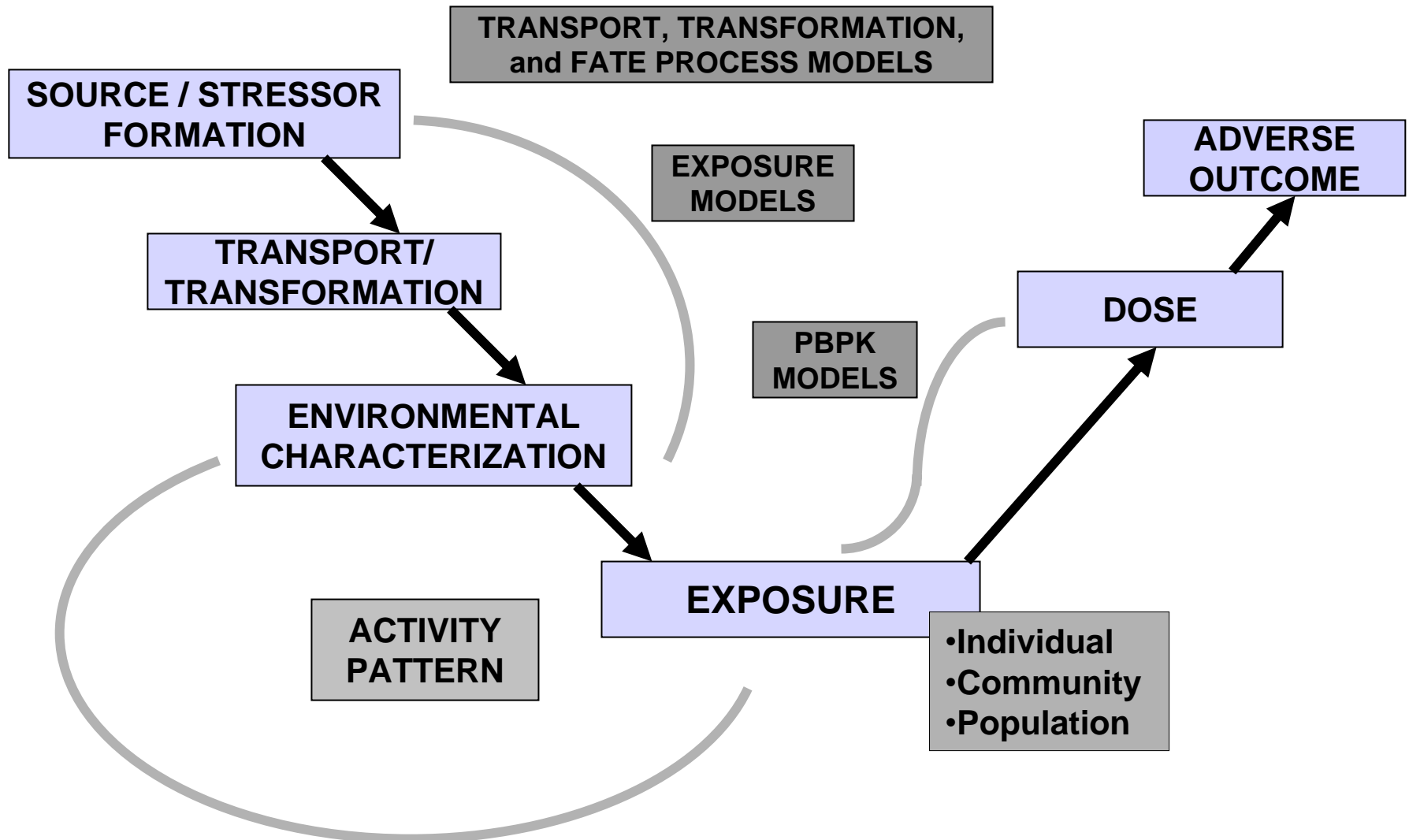
Exposure Assessment

Agent ?? → People

What exposures may be experienced by individuals or populations under real-world conditions?

Course Outline

- Human exposure assessments

- Problem formulation

- Exposure assessment approaches

- Scenario evaluation

- Exposure data

- Exposure models

- Exposure analysis

- Uncertainty and variability

Purpose of Exposure Assessment

TRANSPORT, TRANSFORMATION, and FATE PROCESS MODELS

SOURCE / STRESSOR FORMATION

EXPOSURE MODELS

ADVERSE OUTCOME

TRANSPORT/ TRANSFORMATION

DOSE

PBPK MODELS

ENVIRONMENTAL CHARACTERIZATION

EXPOSURE

ACTIVITY PATTERN

- Individual
- Community
- Population

Human Exposure Assessment

- Exposure characterization is the risk analysis step in which human interaction with the environmental agent of concern is evaluated.

- To assess exposure to a particular agent we need to know
  - Who is exposed (target)
  - How is the target exposed (pathway, route)
  - What is the pattern of exposure (where, how much, how long, how often)

- Sometimes we can measure exposure directly

- Often we need to estimate exposure

Definitions

- Exposure
  - Contact between an agent and a target. Contact takes place at an exposure surface over an exposure period.

- Dose
  - Amount of agent that enters a target after crossing an exposure surface. If exposure surface is an absorption barrier, dose is an absorbed dose/uptake dose; otherwise, it is an intake dose.

Definitions

- ## Exposure pathway
  - Course an agent takes from the source to target.

- ## Exposure route
  - Way in which agent enters target after contact (e.g., ingestion, inhalation, dermal absorption).

- ## Exposure scenario
  - Combination of facts, assumptions, inferences that define situation where potential exposures may occur. May include sources, exposed population, time frame, microenvironment(s), and activities.
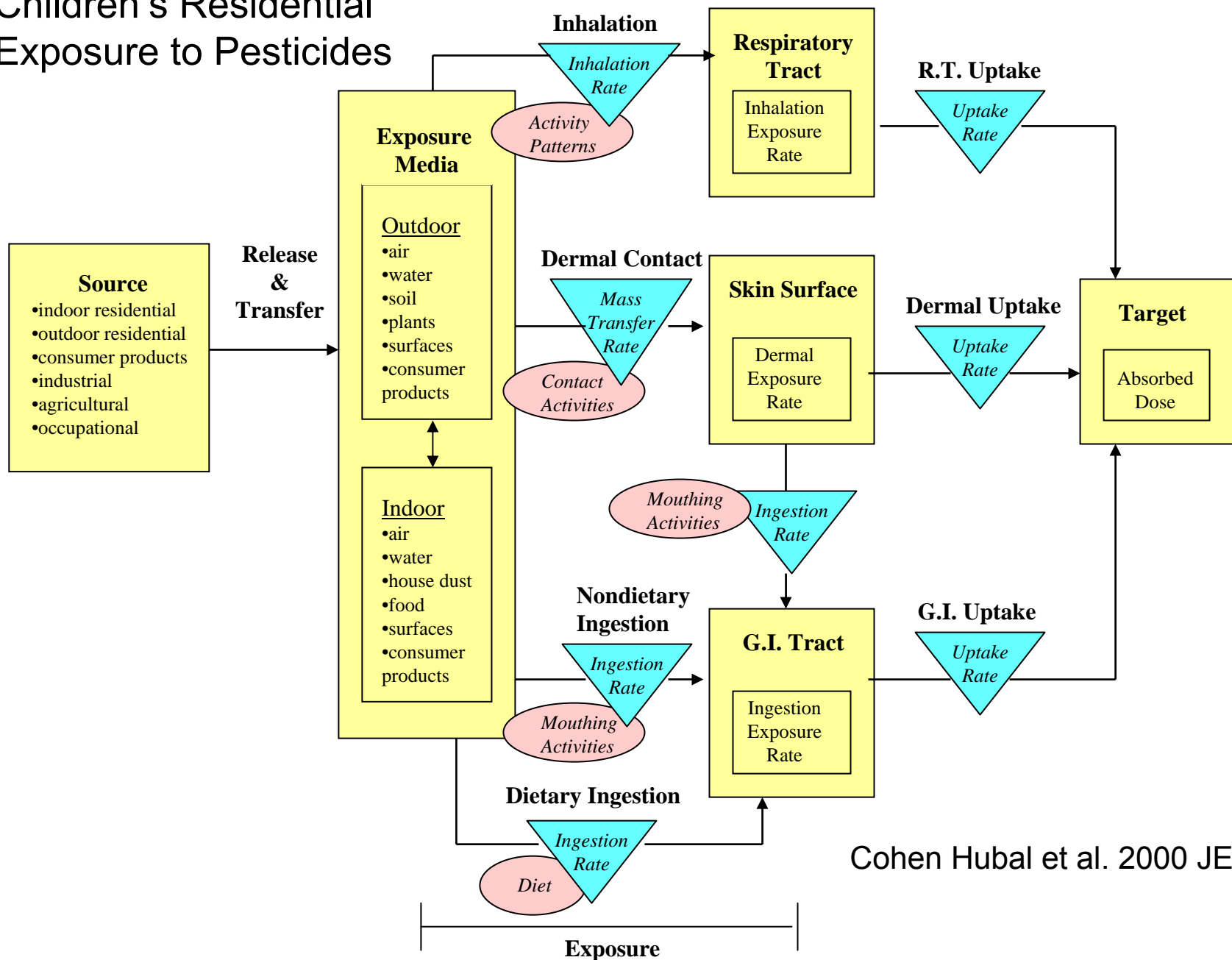
Definitions

- Exposure assessment
  - Process of estimating the magnitude, frequency, and duration of an exposure, along with characteristics of the target exposed. Ideally, describes sources, pathways, routes, and uncertainties.
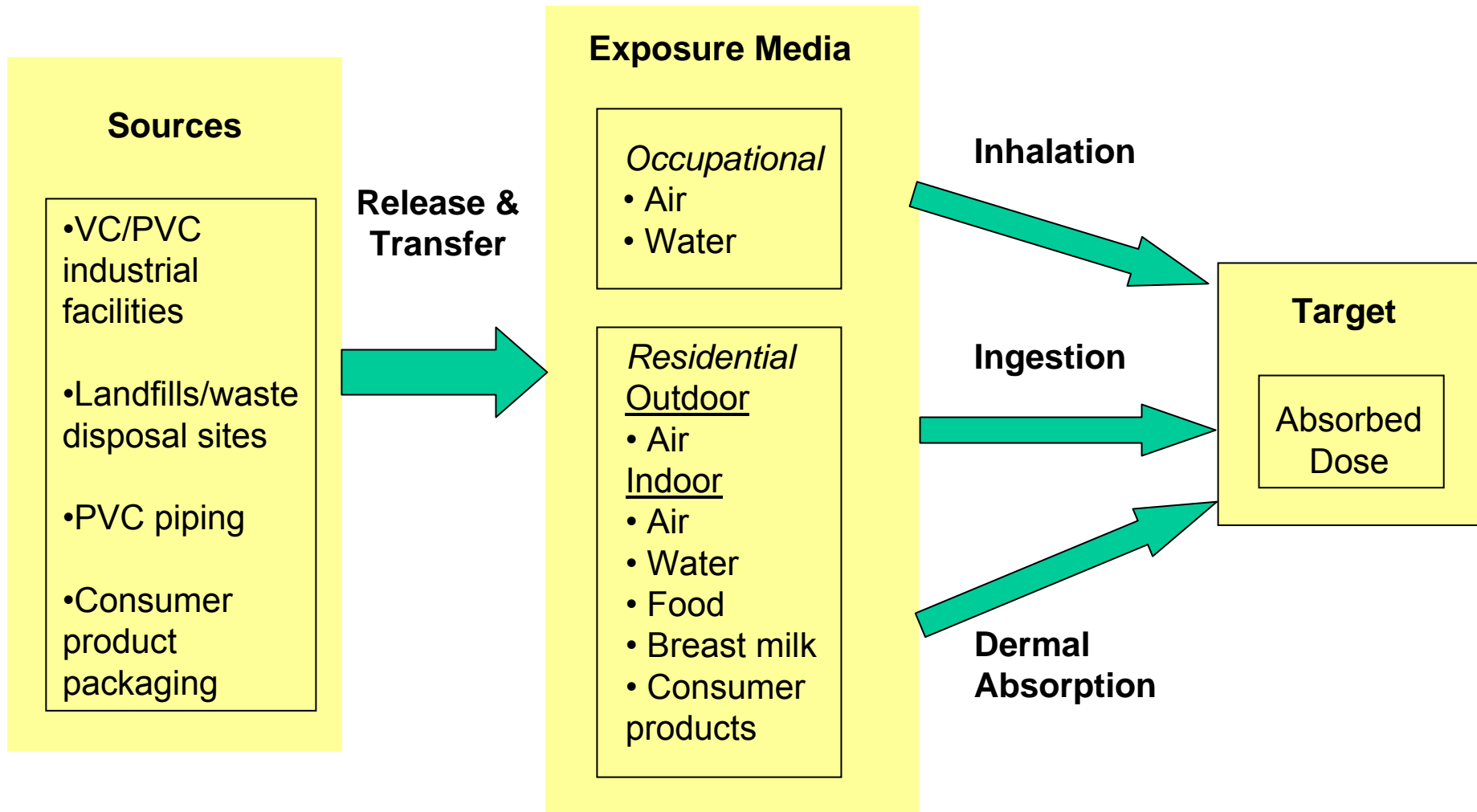
Problem Formulation

- Scope of assessment
  - Scale (national, site specific)
  - Target (vulnerable life stages, subpopulations)

- Develop conceptual model
  - Guide for collection of exposure data and other required information
  - Traditionally, follow source-to-effects paradigm
  - Shift to target-oriented view

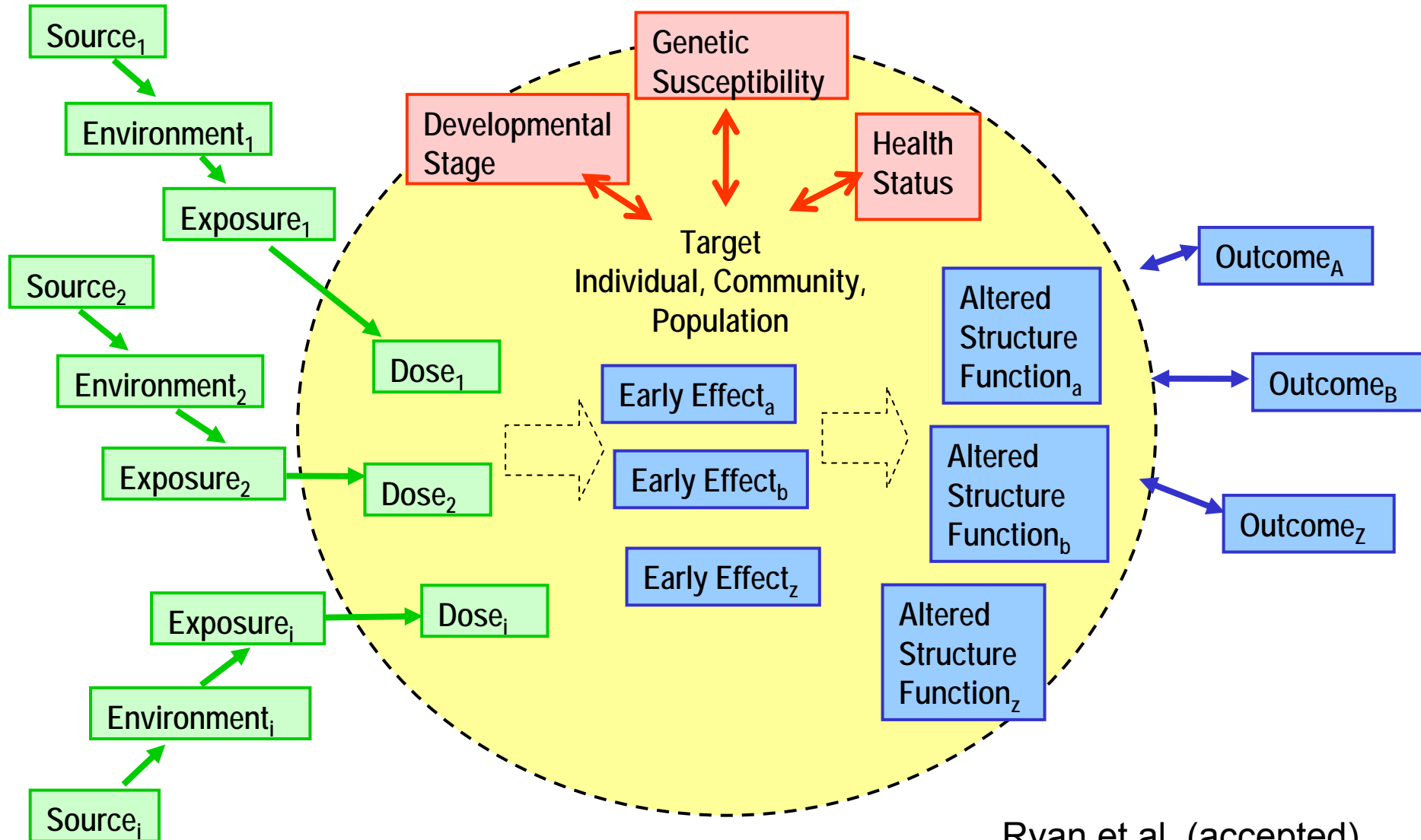# Children's Residential Exposure to Pesticides

Cohen Hubal et al. 2000 JEAEE

Conceptual Model:
Vinyl Chloride (VC) Exposure

Exposure Media

Sources

- VC/PVC industrial facilities
- Landfills/waste disposal sites
- PVC piping
- Consumer product packaging

Release & Transfer

Occupational
- Air
- Water

Residential
Outdoor
- Air
Indoor
- Air
- Water
- Food
- Breast milk
- Consumer products

Inhalation

Ingestion

Dermal Absorption

Target

Absorbed Dose

Target Oriented Model

Ryan et al. (accepted)

Exposure Assessment Approaches

- Questionnaire based metrics (epidemiology)
- Surrogate exposure metrics (ambient measures)
- Exposure measurement (direct or point-of-contact)
- Biomonitoring (dose reconstruction)
- Modeled estimates (indirect or scenario evaluation)

Scenario Evaluation Approach

- Currently, modeled estimates (scenario evaluation) are often used to conduct risk assessments required to make regulatory decisions.

- Identify potentially significant exposure scenarios
  - Chemical Properties, Environmental Sources, Fate, and Transport
  - Population
  - Pathways
  - Exposure Patterns
    - Location, Activities, Behaviors

Chemical Properties, Fate and Transport

Vinyl Chloride

- Molecular weight — 62.4987
- Vapor pressure — 333 kPa
- Solubility in water — 1.1 g/L
- Henry's law constant — 18.8
- Log Kow — 1.38-1.58
- Density — 0.910 g/cm^3
- Log Koc — ---
- State at room temp — Colorless gas
- Formulation/vehicle — ---

Properties at 20 degrees C.
WHO (1999)

Sources

Sources

Vinyl Chloride Sources

- Industrial Sources
  - 27 million tons/year produced world wide
  - Most is polymerized to produce PVC
  - There are no direct consumer uses
- Other Sources
  - Found in and around industrial and municipal landfills/ waste disposal sites

WHO (1999); Keilhorn (2000)

Vinyl Chloride Environmental Fate

- Vinyl Chloride formed from degradation of higher chloroethenes (e.g., trichloroethene TCE) in environmental media

- Degradation of Vinyl Chloride is slow resulting in build up in landfills and surrounding areas, leaching into groundwater

  WHO (1999); Keilhorn (2000)

Population

- ## Population (target)
  - Occupational
  - General
  - Vulnerable life stage or subpopulation

- ## For vinyl chloride
  - Occupationally exposed
  - General population
  - Population near VC/PVC plants or waste disposal sites
  - Developing fetus and breast-fed infant of occupationally exposed mother

Exposure Pathways – Vinyl Chloride

- Inhalation of outdoor air near VC/PVC plants or waste disposal sites
- Inhalation of indoor air near waste disposal sites (subsurface migration)
- Ingestion of contaminated drinking water
- Ingestion of food, beverages packaged in PVC
- Dermal absorption from cosmetics packaged in PVC
- Exposure to fetus from occupationally exposed mother
- Ingestion of breast milk from occupationally exposed mother

Exposure Patterns

- Depending on the exposure assessment, different estimates of exposure and dose may be required
  - Chronic
  - Acute
  - Short-term/ Intermittent

- Locations

- Activities/behaviors

Exposure Patterns

- Exposure over a period of time can be represented by a time-dependent profile of exposure concentration

- Area under the curve of this profile is magnitude of exposure, in concentration-time units
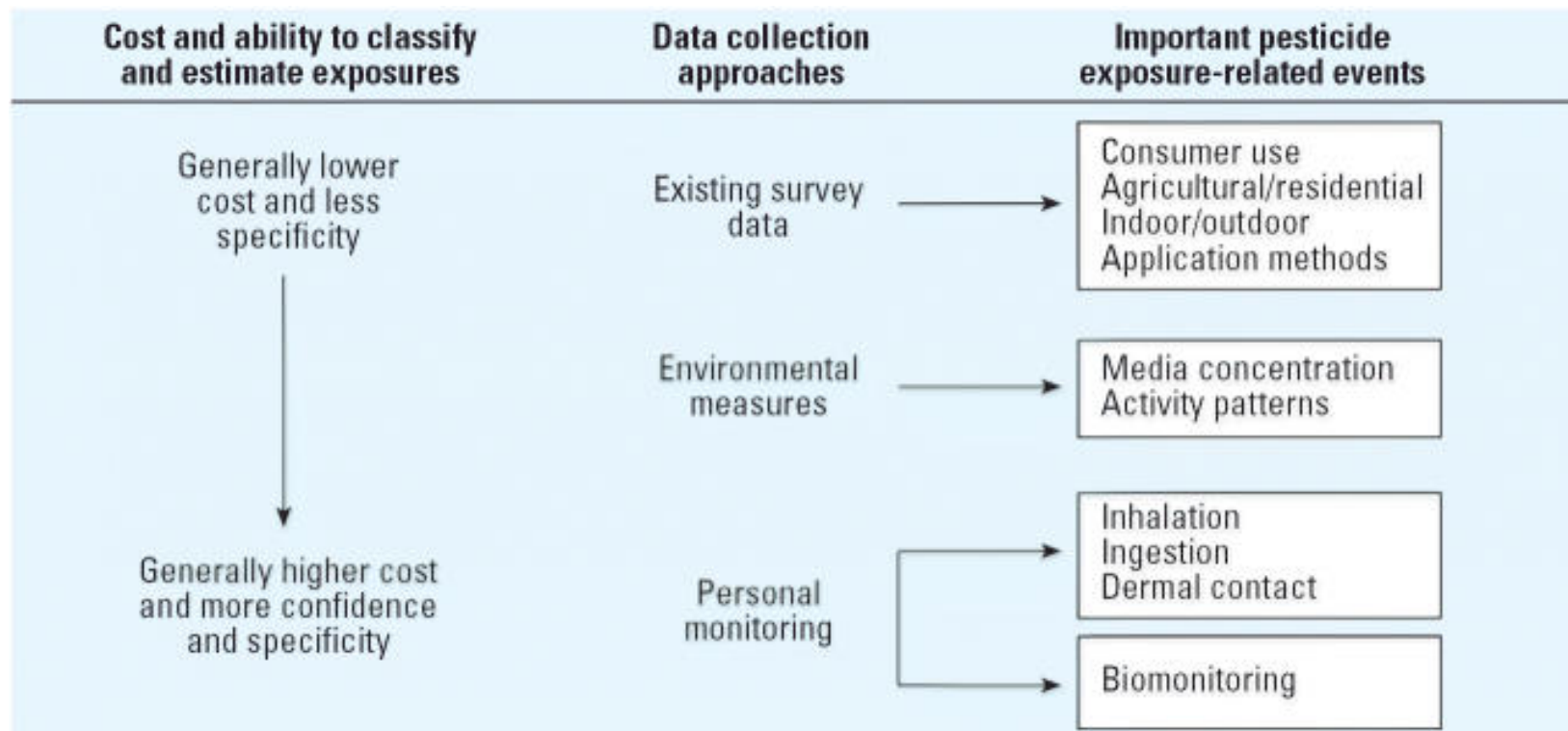
$$E = \int_{t_1}^{t_2} C(t)dt$$

E = magnitude of exposure
C(t) = exposure concentration as function of time
t2 - t1 = exposure duration

Exposure Data

- Exposure measurement data
- Exposure media concentrations
- Exposure factor data
  - Contact rates of target with exposure media
  - Contaminant transfer efficiency from the exposure medium to the portal of entry
  - Contaminant uptake rates through portal of entry
  - Human activities

Exposure Data Collection

Cost and ability to classify and estimate exposures	Data collection approaches	Important pesticide exposure-related events
Generally lower cost and less specificity	Existing survey data	Consumer use Agricultural/residential Indoor/outdoor Application methods
↓	Environmental measures	Media concentration Activity patterns
Generally higher cost and more confidence and specificity	Personal monitoring	Inhalation Ingestion Dermal contact
		Biomonitoring

Biomonitoring Data

- The *National Report on Human Exposure to Environmental Chemicals* (CDC, 2005)
  - Provides an ongoing assessment of the U.S. population's exposure to environmental chemicals using biomonitoring.
  - Measured chemicals or their metabolites in blood and urine samples from a random sample of participants from the National Health and Nutrition Examination Survey (NHANES)
  - Presents exposure information for the U.S. population for 148 chemicals

Human Exposure Measurement Data

- **HEDS** (Human Exposure Database System)
  - Integrated data repository system that contains chemical measurements, questionnaire responses, documents, and other information related to EPA human exposure research studies
  - NHEXAS (National Human Exposure and Assessment Study)
  - CTEPP (Children's Total Exposure to Pesticides and other Persistent Organic Pollutants)

Human Time-Activity Data

- **CHAD** (Consolidated Human Activity Database)

  Contains activity/and questionnaire data obtained from pre-existing human activity studies collected at city, state, and national levels

Dietary and Consumer Product Use Data

- **FDA's Total Diet Survey**
  - Market basket survey
  - Food purchased from grocery stores 4x per year
  - From 3 cities in each of 4 US geographic regions
  - Foods prepared for consumption and analyzed

- **EPA's Source Ranking Database (SRD)**
  - Developed for screening a large number of indoor air pollution sources
  - Compilation of product composition information from a variety of sources

Exposure Factor Data

- US EPA Exposure Factors Handbook (1997)
- US EPA Child-Specific Exposure Factor Handbook (2006)
- Exposure Factors (Intake and Uptake)
  - Drinking water consumption rates
  - Specific food consumption rates
  - Incidental soil ingestion rates
  - Pulmonary ventilation rates
  - Dermal surface areas

Recommended Values for Inhalation Rate

Activity Level	Age Range (years)	Males		Females	
		Mean m³/day	N	Mean m³/day	N
Long-term Exposures					
(All)	birth to <1 year	8.76	419	8.53	415
	1 to <2 years	13.49	308	13.31	245
(Percentiles see Tables 7-13 and 7-14)	2 to <3 years	13.23	261	12.74	255
	3 to <6 years	12.65	540	12.16	543
	6 to <11 years	13.42	940	12.41	894
	11 to <16 years	15.32	1337	13.44	1451
	16 to <21 years	17.22	1241	13.59	1182
Short-term Exposures					
Sleep or Nap	birth to <1 year	4.44	419	4.20	415
	1 to <2 years	6.48	308	6.61	245
(Percentiles see Tables 7-15 and 7-16)	2 to <3 years	6.64	261	6.57	255
	3 to <6 years	6.28	540	6.02	543
	6 to <11 years	6.64	940	6.28	894
	11 to <16 years	7.57	1337	6.93	1451
	16 to <21 years	7.65	1241	6.34	1182

U.S. EPA. (2006) Child-specific exposure factors handbook (external review draft).

Exposure Models

- Aggregate Models
- Dietary Models
- Waste Site Models
- Consumer Product Models
- Air Models
- Occupational Models

Exposure Analysis

- Screening level assessment
- Refined assessment
- Supplemental data collection

- Aggregrate assessments address exposure to an agent by multiple sources, routes, pathways

- Cumulative assessments address exposures to multiple agents or stressors

Exposure Algorithms

- For each route, the algorithm mathematically expresses exposure as a function of
  - Chemical concentration in the exposure medium
  - Contact rate
  - Rate of transfer from the exposure medium to the portal of entry
  - Exposure duration

Example: Inhalation Exposure

For each exposure event, inhalation exposure is defined as follows:

$$E_{inhale} = C_{air} \times IR \times AB \times ED / BW$$

E_{inhale} = exposure (mg/kg/d)

C_{air} = air concentration (mg/m^3)

IR = respiration rate (m^3/h)

AB = fraction absorbed

ED = exposure duration (h/d)

BW = body weight (kg)

Vinyl Chloride Media Concentrations

- Levels of VC in air and water very low for locations distant from industrial sources.
  - Ambient air concentrations ND-24 ug/m^3
  - Drinking water ND – 1.1 ug/L

- Few reports on VC levels found in food, pharmaceutical or cosmetic products in recent years.
  - Latest data (1990s) bottled drinking water 0.01-0.08 ug/L

- Infrequent use of biomonitoring for VC exposure

- Assessment for occupationally exposed parents and their children requires information for occupational environment

WHO (1999)

Vinyl Chloride Media Concentrations

- Exposure assessments for populations near sites requires site-specific information

- Ambient air concentrations
    - US residential in vicinity of VC/PVC plants up to 3200 ug/m^3 (late 1970s)

- Indoor air concentrations
    - Homes near landfills up to 1 g/m^3 (early 1990)

- Groundwater samples 50-500 µg/L near industrial sites

- Drinking water
    - (likely contaminated systems) ND – 8 µg/L

WHO (1999)

VC Exposure Estimates: Inhalation

- Estimate from the mid 1980s of the respiratory intake of VC reported for the USA ranged from 0 to 48.3 mg/day

    Cair = 0 to 2.1 mg/m^3

    IR = 23 m^3/day

- However, it was estimated in the mid 1990s that over 100,000 Californians living near landfills, may be exposed to VC levels of 2.59 g/m^3 (1 ppb) or more

WHO (1999)

VC : Drinking Water Ingestion

- 1985 estimated drinking water intake exceeded
  - 1 g/L for 0.9% of the population,
  - 5 g/L for 0.3%
  - 10 g/L for 0.1% of the population

- Daily VC intakes = 2, 10 and 20 g/day
  BW = 70 kg
  IR = 2 L water/day

- Maximal values were120 g/day

WHO (1999)

Uncertainty and Variability

- Variability, sensitivity and uncertainty analyses are conducted to determine impact of the available exposure data on the resulting analysis

- Use of probabilistic techniques to address variability

Conclusion

- Results of the exposure characterization are iterated with the hazard and dose-response
  - critical windows of susceptibility identified in hazard analysis
  - important exposure periods identified in exposure analysis
- Results of exposure analysis feed into the risk characterization
- Used to make public health policy and regulatory decisions