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Job Exposure Matrix, a fascinating way to learn about occupational and environmental exposures and their health effects

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This Is Public Health

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Occupational exposure assessement: Why? and How ?

- Regulatory reasons
  - To demonstrate compliance with standards and recommendations
- To inform and adapt risk management
- OSH & epidemiological research
  - Exposure or Dose-response relation
  - To develop and test sampling methods and devices
- Policy and public health decisions
  - To assess health impact
  - To assess the effectiveness of prevention measures

- Routine Vs Control measurements
  - Stationary
  - Personal (Breating Zone)
  - Biomonitoring (Regular Vs Punctual)
- Contemporary, prospective, retrospective

Type of data	Quality of dose approximation
Individual measurement of **body or organ-specific burden/dose** for all workers	
Individual measurement of the **external concentration** in PBZ for all workers	
Measurement of **external concentration at workstations** or in specific industrial areas	
Ordinal / relative classification of jobs or tasks by exposure level	
Duration of employment in industry	
Binary ranking (yes/no) by industry job	

JEM

Job Exposure Matrix: What is it ?

- One of the methods of exposure assessment
- Based on OH expertise, Exposure measurement data, and/or Stat. Modelling
- Database or a program associating data on occupational exposure to a hazard(s) with jobs

Jobs \ Exposures	Hazard 1	Hazard 2	Hazard 3
Job 1	x	y	z
Job 2	x	y	
Job $_i$	x	y	z

Exposure estimates

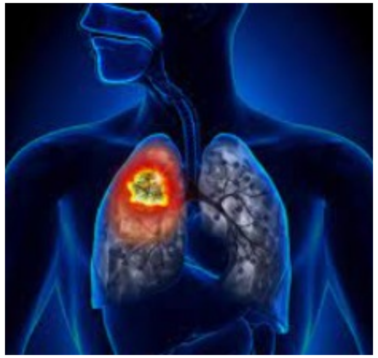
- **Exposure estimates**

  Presence, Probability, Frequency, Intensity of exposure...

- Qualitative, Semi-quantitative or Quantitative

Jobs \ Exposures	Hazard 1	Hazard 2	Hazard 3
Job 1	yes	1	5 $\mu g/m^3$
Job 2	no	0	0, 0001 $\mu g/m^3$
Job $_i$	yes	3	15 $\mu g/m^3$

Job Exposure Matrix: How does it work ?



Mr. X
Occupational History

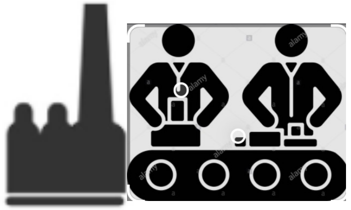
Job 1: 10y
Job 2: 25y
Job 3: 5y

Jobs \ Exposures	Asbestos	RCS	Zn
Job 1	yes	1	5 µg/m³
Job 2	no	0	0, 0001 µg/m³
Job 3	yes	3	15 µg/m³

Cumulative exposure — RCS: 1*10 + 0 + 3*5=25 — Zn: 5*10+0+15*5=125 µg/m³y

Cum. exposure duration — Asbestos: 10 + 5 = 15 y

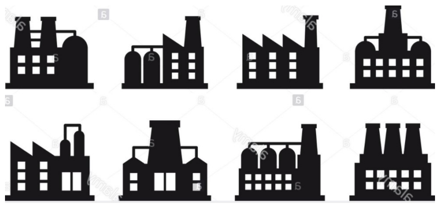
Job Exposure Matrix: Which type ?



Company/plant specific

AREVA Pierrelatte nuclear plant
Parisian subway PM JEM

Occupational cohort study



Industry-specific

Chemical industry & TiO2
Agriculture & PPP

Industrial cohort study

Case-control studies nested within cohorts

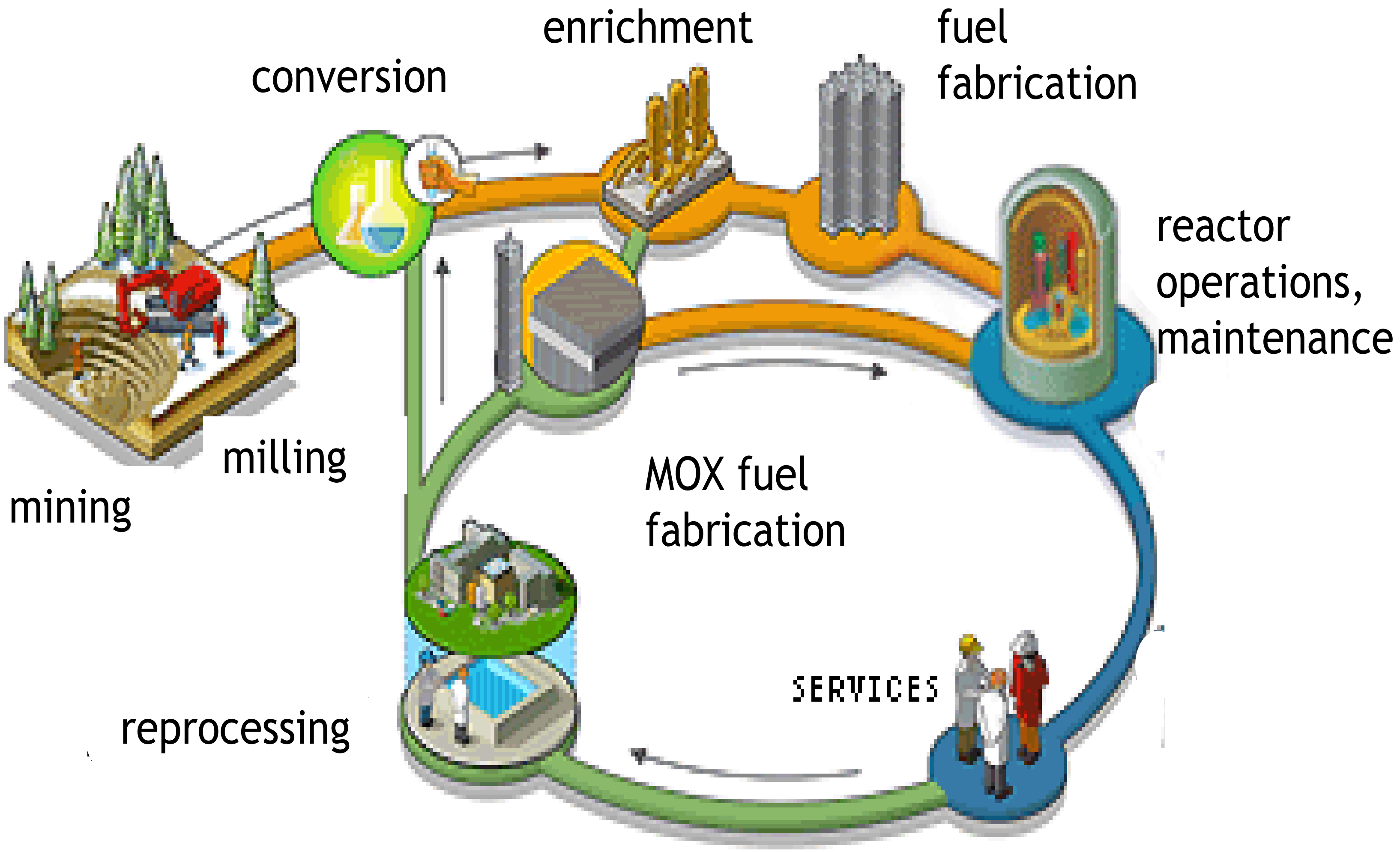
Generic (general population)

OMEGA–NET
SYN-JEM, FIN-JEM

Case-control studies

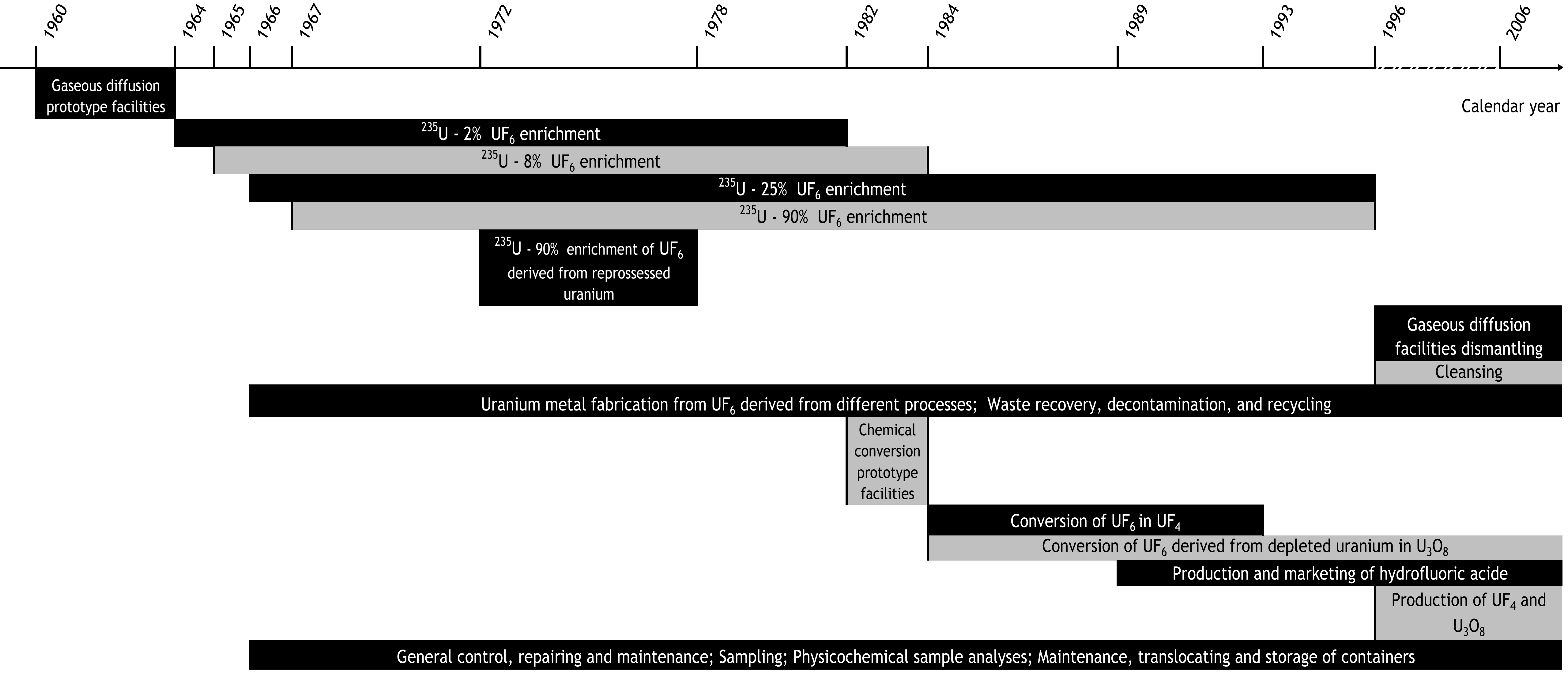
How to create a JEM ?

1st exemple: semi-quantitative JEM for AREVA Pierrelatte plant



How to create a JEM ?

1st exemple: semi-quantitative JEM for AREVA Pierrelatte plant



How to create a JEM ?

1st exemple: semi-quantitative JEM for <u>AREVA Pierrelatte plant</u>

<u>Jobs:</u> homogeneous occupational categories defined according to function, task, facility, and time-period from 1960 trough 2006.

<u>Exposures:</u> 6 categories of uranium compounds and 16 categories of chemicals known as being carcinogenic, mutagenic or toxic that have been ever in used at the plant.

Assessment procedure

<u>Expert committee</u> 23 experts (occupational hygienist, security and radioprotection engineers, occupational physician, toxicologists, chemists, nuclear physicist, dosimetrist, epidemiologists) for defying JEM components

<u>Evaluator committee:</u> 353 evaluators (171 retired workers and 182 active AREVA NC Pierrelatte workers) with a good knowledge of occupational conditions for a period 1960-2

Guseva Canu et al. RESP (2009)
Guseva Canu et al. IJHEH (2010)
Guseva Canu et al. IJHEH (2011)

JEM ELABORATION

Definition of types of exposure (*A*), jobs (*j*), and periods (*p*) of stable exposure by experts

Assessment of exposure indicators (frequency (F_{Ajp}) and quantity (Q_{Ajp}) of handeled pollutant) by active and retired workers

Keyboarding of assessment results

Statistical examination of Q_{Ajp} and F_{Ajp} scores

Experts' arbitration on a final score for each job-period (*jp*) pair

Final JEM with 232 job-periods and 2 exposure indicators (Q_{Ajp} and F_{Ajp}) for 22 exposure agents (*A*)

JEM VALIDATION

Examination of internal consistency of JEM by experts

Examination of JEM sensitivity and specificity and its agreement with data from medical records

RECONSTRUCTION OF INDIVIDUAL JOB HISTORIES

Computing of employement duration for each job-period (D_{pj}) on the basis of personnel records

$$E_A = \sum_{j=1}^{73} \sum_{p_j} F_{Apj} \times Q_{Apj} \times D_{pj}$$

COMPUTING OF INDIVIDUAL CUMULATIVE EXPOSURE SCORE (E_A)

EXAMINATION OF CORRELATION BETWEEN CO-EXPOSURES

Before this JEM

Cohort study of mortality among AREVA Pierrelatte workers (n=2897)

Average cumulative external dose 17.5 [0.05–217.2] mSv over 20-y dosimetry surveillance

Outcome	Obs	Lag	RR100mSv	IC-95%		P trend
Cancereous diseases	214	10y	0,93	0,85	1,08	0,28
Lung cancer	53	10y	0,89	0,79	1,23	0,33
Hemato-lymphopoetic cancer	21	2y	1,05	0,78	3,36	0,96
Cardiovascular diseases	111	5y	1,11	0,90	1,75	0,39
Ischaemic heart disease	47	5y	1,06	0,78	2,32	0,75
Cerebro-vascular disease	31	5y	0,92	0,70	1,75	0,62

Obs – observed deaths ; Lag – latency time (years) ; RR100MSv – Risque relatif per 100 Sv ; IC-95%– confidence intreval. *(Guseva Canu et al, 2014)*

Conclusion ?

Absence of assiociation ?

Inapropriate exposure metric ?

JEM application in the dose – response analysis

Mortality due to cardiovascular diseases (111 cases)

Cox proportional hazards model; Adjustment for attained age, calendar period, SES, sex, TCE, aromatic solvents, heat, shift work *Guseva Canu et al, 2013*

	Uranium naturel (UN)			Uranium de retraitement (URT)		
Exposure variables	Type-F	Type-M	Type-S	Type-F	Type-M	Type-S
Statut d'exposition annuelle (Binaire)						
Exposé Vs Non-exposé	2,00 (1,00-4,02)	**1,65 (1,06-2,56)**	**1,85 (1,20-2,86)**	**1,80 (1,06-3,10)**	**4,76 (2,22-10,2)**	**6,45 (2,89-14,4)**
Niveau d'exposition (catégorielle, 3 classes)						
Négligeable	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Modérée	2,01 (1,01-4,03)	1,45 (0,76-2,04)	1,45 (0,89-2,37)	1,36 (0,72-2,58)	1,46 (0,34-6,25)	**5,54 (2,31-13,3)**
Forte	1,88 (0,83-4,29)	**2,04 (1,14-3,49)**	**4,62 (2,37-9,00)**	**4,24 (1,85-9,74)**	**12,1 (5,08-28,9)**	**16,04 (3,45-74,6)**
...osition (quantitative continue)						
...n	**1,07 (1,03-1,11)**	**1,04 (1,01-1,08)**	**1,07 (1,04-1,11)**	**1,13 (1,06-1,19)**	**1,19 (1,11-1,27)**	**1,20 (1,12-1,28)**

Zhivin et al, 2018

Table 5 Relationship between CSD mortality risk and uranium lung dose

Model	EOR/mGy (95% CI)
Unadjusted†	0.2 (0.02 to 0.6)
Adjusted for smoking†	0.2 (0.01 to 0.6)
Adjusted for BMI†	0.2 (0.01 to 0.5)
Adjusted for BP†	0.2 (0.01 to 0.6)
Adjusted for total cholesterol†	0.2 (0.01 to 0.6)
Adjusted for glycaemia†	0.2 (0.02 to 0.6)
Adjusted for external γ-radiation dose†	0.2 (0.02 to 0.6)
Fully adjusted†‡	0.2 (0.004 to 0.5)

- ✓ Dose-response relationship with exposure duration and intensity
- ✓ Effect of isotopic composition (URT >>> UN)
- ✓ Effect of solubility (inverse relationship)
- ✓ Important for Hazard identification
- ✓ Time and cost-friendly
- ✓ Widely used: EURODIF JEM (FR), Sellafield JEM (UK), NIOSH (USA)

How to create a JEM ?

2nd exemple: generic JEM «MatPUF» for Ultrafine Particle (UFP) exposure

Methods *(Audignon-Durand et al. 2021)*

1 - Literature review

57 work processes and chemical composition of UFPs emitted

2 - Expert panel

Probability and frequency of UFP exposure were assessed for each combination of occupational code and process

Occupational codes defined by the ISCO 1968 classification

UFP & lung cancer (OR = 1.51; 95% CI: 1.22–1.86)

UFP & brain tumors (OR = 1.69; 95% CI: 1.17–2.44)

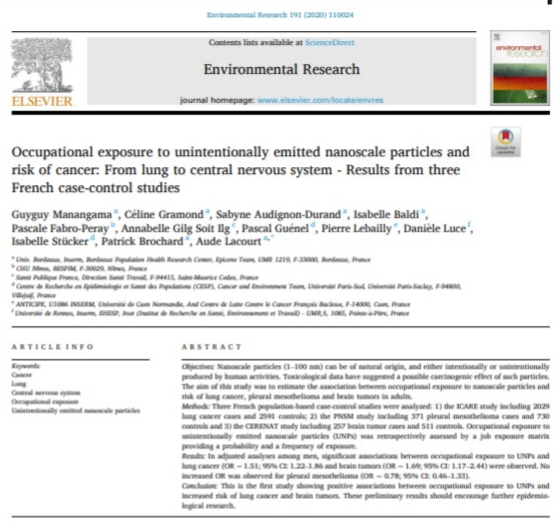
UFP & pleural mesothelioma (OR = 0.78; 95% CI: 0.46–1.33)

veral processes

Method used in MATGENE and MATPHITO programs (France)

- Estimation of PAF and DALYs
- Analytical epi-studies

4. Temporal axis	Historical period of exposure: start and end years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Occupational exposure to unintentionally emitted nanoscale particles and risk of cancer: From lung to central nervous system - Results from three French case-control studies

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ARTICLE INFO
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Central nervous system
Occupational exposure
Unintentionally emitted nanoscale particles

ABSTRACT
Objectives: Nanoscale particles (1–100 nm) can be of natural origin, and either intentionally or unintentionally produced by human activities. Toxicological data have suggested a possible carcinogenic effect of such particles. The aim of this study was to estimate the association between occupational exposure to nanoscale particles and risk of lung cancer, pleural mesothelioma and brain tumors in adults.
Methods: Three French population-based case-control studies were analyzed: 1) the ICARE study including 2029 lung cancer cases and 2591 controls; 2) the PNSM study including 371 pleural mesothelioma cases and 730 controls and 3) the CERENAT study including 257 brain tumor cases and 511 controls. Occupational exposure to unintentionally emitted nanoscale particles (UNPs) was retrospectively assessed by a job exposure matrix providing a probability and a frequency of exposure.
Results: In adjusted analyses among men, significant associations between occupational exposure to UNPs and lung cancer (OR = 1.51; 95% CI: 1.22–1.86 and brain tumors (OR = 1.69; 95% CI: 1.17–2.44) were observed. No increased OR was observed for pleural mesothelioma (OR = 0.78; 95% CI: 0.46–1.33).
Conclusion: This is the first study showing positive associations between occupational exposure to UNPs and increased risk of lung cancer and brain tumors. These preliminary results should encourage further epidemiological research.

Manangama et al. Env Res

How to create a JEM ?

3rd exemple: «SYN-JEM» country-, job-, and time period-specific quantitative JEM for 5 lung carcinogens *(Peters et al. 2016)*

Data used

1 - ExpoSYN database

- 356 551 measurements from 19 countries: 140 666 personal and 215 885 stationary data points
- RCS (42%), asbestos (20%), chromium (16%), nickel (15%), and PAH (7%), covering a time period of >50 years
- **Only personal measurement data used**

2 - General population JEM (DOMJEM): no, low, or high exposure levels to all job titles listed in ISCO-68 (Peters *et al.*, 2011)

Statistical method

A linear mixed-effects model, using the same structure for all five agents.

- Random effects terms: region/country and job title, for which best linear unbiased predictors (BLUP)
- Fixed effect terms: Sampling duration, Year, Measurement strategy, Analytical method
- Model predictions provides an **annual geometric mean (GM)** exposure level to any agents for a given job, region, year
- Approaches allows to combine individual-/subgroup-level and group-level exposure information using shrinkage
- estimators to maximize accuracy and precision of the final JEM
- Prior exposure rating allows calibration of exposure levels by a weighted mean of exposure measurements
- Inspired by Friesen at al 2012 and Bayesian calculations (Verbeke and Molenberghs, 2000)

Application

Assessment of cancer risks associated with low levels of occupational exposure and the joint effects of smoking (IARC)

How to create a JEM in Switzerland ?

Data available

1 – SUVA database of occupational exposure measurements (no access for researchers)

2- Data on UV environmental exposure and radon

3 - Survey of active population and Suisse health survey by Swiss Federal Statistical Office (SFSO)

- Irregular working hours, psychosocial risk factors, physical activity, smoking
- Prevalence of exposure, frequency, sometimes intencity
- Since 1990

4 – Cohorts:

- One industrial cohort (Swiss railway employees, (R*öösli et al 2007*))
- No occupational cohort
- Many general population cohorts: SNC, SAPALDIA, SKIPOGH, CoLaus/PsyCoLaus, SHeS
  - Occupation history completeness ± satisfactory, ± possible to reconstruct
  - Few exposure data

5 – Disease registries (cancer, ORTS, …):

- Quality of occupational data deemed insufficient *(Plys et al, submitted)*

⇒ **Need of case-control studies with detailed occupation history and JEMs**

⇒ **Suisse solution: use avalable JEMs**

- Directly by applying the region-specific EU or intrenational JEMs
- As prior for creating Swiss-specific JEMs

Exemple: How to create a Swiss-specific JEM for smoking?

Rational:

Given the frequent lack of smoking status data in Swiss datasets, a Swiss Smoking JEM could provide the tool to reconstruct such data when not available

Datasets:

1. Swiss Health Survey (SHS) by SFSO
2. Job-Exposure matrix (DJEM) constructed by the Department of Occupational and Environmental Medicine (DOEM), Bispebjerg Hospital, Denmark
   - Jobs coded using ISCO 88
   - Smoking probability and intencity per Job, Sex, Age, and Calendar Year

Exemple: How to create a Swiss-specific JEM for smoking?

1. Retrieve estimated **smoking status probabilities** from DJEM, stratified by age group, gender, and occcupation (ISCO-88) **and compute log of odds**.
2. Use the Swiss Health Survey (SHS), stratified similarly to DJEM, to estimate via a **mixed logistic regression** the probabilities of being a smoker. Compute **the log of odds**.
3. Estimate the Pearson's correlation between the log of odds computed from DJEM and SHS
4. **Estimate means and variances of log-odds**
5. Use information from step 4 **to build a prior for the Bayesian logistic regression** (covariates: age group, gender, ISCO-88) to **estimate smoking status probabilities**
6. **Same for smoking intensity**
7. Check empirically the reliability of the Swiss JEM, by comparing the estimated probabilities given by the Swiss JEM and a different Swiss dataset that contains smoking status data.

💣 Need of coding and recoding occupations from Swiss nomenclature into ISCO (88, 68) or national ones

procode

Funding: SECO & FOPH

Procode: A Machine-Learning Tool to Support (Re-)coding of Free-Texts of Occupations and Industries.
Savic N, Bovio N, Gilbert F, Paz J, Guseva Canu I.
Ann Work Expo Health. 2021 Jun 19:wxab037. doi: 10.1093/annweh/wxab037. Online ahead of print.

Take-home messages

- 💣JEM is often the only method for retrospective exposure assessement
- 💣 It is particularly appropriate
  - ⇒for analytical epi-studies of diseases with long latency
  - ⇒ for rare diseases (using case-control study design)
- 💣JEM quality depends on the quality of the data and resources available
- 💣Even a semi-quantitative JEM can be more relevant than an individual quantitative measure if it correctly reflects
  - ⇒ the complexity of the exposure
  - ⇒ the appropriate exposure metric
- 💣 Relevant for hazard identification and emergent risk assessment (e.g., nano)
- 💣 Very useful in research in OSH

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Thank you for your attention !

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