Short-term Physical Effects Oil Spills

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Background

- Crude oil
- Exposures
- Acute toxic effects
- Physical injuries
- Target population
- Summary

Crude oil

- Crude oil (liquid petroleum) occurs naturally and consists of a complex mixture of hydrogen and carbon
- When a spill occurs:
  - Oil slick on the surface
  - Gases volatile organic compounds (VOCs) evaporate (small amount dissolves in water)
  - Oil residue + water → thick mousse
  - Part of oil sinks + suspended particulate matter → tar balls
  - Oil dispersants → break up oil on the water surface → tiny oil drops easily mix with the water and get diluted
  - Over time oil waste disintegrates

Short-term Physical Effects Exposures

- **Chemical exposures**
  - **Crude oil** may include benzene and other volatile organic compounds (VOCs – benzene, ethylbenzene, toluene, xylene, napthalene), oil mist, polycyclic aromatic hydrocarbons (PAHs), diesel fumes and heavy metals (aluminum, cadmium, nickel, lead and zinc)
  - **Oil dispersants** may include sulfonic acid salt (detergent), propylene glycol, 2-butoxyethanol (solvent) and petroleum distillates (mixture of paraffins that may contain a small amount of aromatic hydrocarbons)
- **Physical hazards** may include ergonomic hazards, excessive noise levels, sun exposure and heat stress; injuries may occur due to slips, trips

Acute Toxic Effects – Crude Oil

Chemical	Route of exposure	Symptoms*
VOCs (ethylbenzene, xylene) PAH	Dermal (contact)	**Skin/mucous membranes:** erythema (redness), edema (swelling), irritation, dermatitis (rash, blisters)
VOCs (benzene, ethylbenezene, xylene)	Inhalation (air) Contact	**Ocular (eyes):** redness, soreness, watering, itching
VOCs (benzene, ethylbenzene)	Inhalation (air)	**Respiratory:** cough, throat irritation (dry, scratchy, sore), shortness of breath, wheezing
VOCs (benzene, toluene)	Inhalation (air)	**Neurological:** nausea/vomiting, headache, dizziness, irritability, confusion, weakness of extremities
VOCs	Ingestion (food, water)	**Gastrointestinal tract disturbances**: transient nausea, possibly vomiting, and self-limiting diarrhea

* Symptoms more pronounced in sensitive individuals

Acute Toxic Effects – Oil Dispersants

Chemical	**Route of exposure**	**Symptoms***
2-butoxyethanol, Petroleum Distillate (oil mist)	Dermal (contact)	**Skin/mucous membranes:** irritation of skin
2-butoxyethanol Petroleum Distillate (oil mist, aromatic hydrocarbons)	Inhalation (air) Contact	**Ocular (eyes):** watering, itching
2-butoxyethanol Petroleum Distillate (oil mist, aromatic hydrocarbons)	Inhalation (air)	**Respiratory:** cough and throat irritation

* Symptoms more pronounced in sensitive individuals

Physical Injuries

Risk factor	Outcome
Slippery or uneven working surfaces	Slips, trips and falls
Use of tools, equipment, machinery and tools, working with wild animal (birds, fish)	Injuries
Strenuous work schedules, heavy physical workload, long duration of work	Fatigue and lumbar pain
Exertion, hot environment	Heat-related health conditions

Target Population

- **Seamen and rescue workers (cleanup, bird cleaning, coast guards etc.)** working in close proximity to oil spill
  - Exposed to many different chemical, physical and psychological hazards
- **Residents** living in close proximity to the oil spill
  - Exposed to poor air quality, acute and chronic chemical exposure, psychological hazards ; pregnant women and young children more vulnerable
- **People eating fish and seafood** from the areas with oil spill
  - Possible exposure to toxic chemicals due to ingestion of contaminated seafood
- **Tourists and people** using affected beaches
  - Chemical exposure

Results from Previous Studies of Oil Spills from Supertankers

- Study Characteristics
- Outcome/Exposure
- Results
  - Toxic effects
  - Injuries
  - Genotoxicity/endocrine effects
- Conclusions

Epidemiological Studies on Tanker Oil Spills

	Vessel name	Date	Spill size (tons)	Location
1	Exxon Valdez*	24 Mar 1989	37,000	USA
2	MV Braer	5 Jan 1993	85,000	UK
3	Sea Empress	15 Feb 1996	72,000	UK
4	Nakhodka	2 Jan 1997	> 6,000	Japan
5	Erika	12 Dec 1999	20,000	France
6	Prestige	19 Nov 2002	63,000	Spain
7	Tasman Spirit	26 Jul 2003	37,000	Pakistan

* Examined only psychosocial end points

Only 7 of 38 supertanker oil spills studied to date

Study Characteristics of Previous Studies on Oil Spills

- **Study design**: Most were cross-sectional studies; involves studying a subset of a population with regard to exposure and outcome at the same time, in which, groups can be compared (exposed vs. unexposed)
- **Exposure:** Except for one study, none had done quantitative exposure measurements; used surrogates of exposure:
  - Community: distance from the incident, living along the coast
  - Cleanup operations crew: type of job, duration
- **Outcome Ascertainment:**
  - Acute toxic symptoms - standard questionnaires
  - General health – standard questionnaire
  - Specific organ functioning – lung, kidney and liver function tests
  - Injuries - questionnaire
  - Genetic toxicity - comet assays, micro nucleus tests, SCE and metabolic genetic polymorphisms
  - Endocrine toxicity- blood (plasma) concentrations of prolactin and cortisol levels

MK Braer (UK, 1993)
Summary of Epidemiologic Studies

Study characteristics	Exposure/Outcome	Results
Cross sectional (Campbell et al. 1993) Immediate **Community* all ages** Exposed residents (N=420) within 4-5 km of the spill Controls living 95 km away (N=92)	Questionnaires of acute symptoms Peak expiratory flow, hematology, liver and renal function tests Blood and urine toxicology screening	**Toxic Symptoms** Major health effects on days 1 and 2 (neurological, ocular (eyes), respiratory) **Lung, liver and kidney function** No significant differences between exposed and controls for any of the biomarkers **Exposure screening** Toxicological studies did not show any exposure known to affect human health
Cross sectional (Campbell et al. 1994) Follow up after 6 months **Community* all ages** Residents (N=344) and controls (N=77)	General health questionnaire Peak expiratory flow, urine analysis, hematology, and liver and renal function tests	**General health** Mean general health questionnaire score of exposed significantly greater than controls **Lung, liver and kidney function** Lung function within normal range No change in biomarker levels between the two time periods

MV Braer (UK, 1993) – cont'd…

Study characteristics	Outcome	Results
Cross sectional (Crum, 1993) Immediate **Community children** Children living close to shipwreck (N=44) at 3 days and (N = 56) at 9–12 days after oil spill	Peak expiratory flow rate	**Lung function** Peak expiratory flow rates were within the normal range at 3 days and at 9-12 days No deterioration seen over the study period
Longitudinal (Cole et al. 1997) One year follow-up **Community (30–49 years)** Genotoxicity in residents (N= 26) and controls (N=9) at 3 sampling times (10 days, 10 weeks and 1 year after the incident)	Primary DNA damage - DNA adducts in the mononuclear cell fraction and frequency of *hprt* mutations in T-lymphocytes	**Genotoxicty** No evidence of genotoxicity

Sea Empress (UK, 1996)
Summary of Epidemiologic Studies

Study characteristics	Outcome	Results
Cross-sectional (Lyons et al.1999) Immediate (7 weeks after the incident) **Community (18–65 years)*** Residents (N=539) controls (N=550)	Questionnaires of acute symptoms	**Toxic symptoms** Exposed had significant increase in neurological, ocular (eyes) and respiratory symptoms
Cross-sectional (Gallacher et al. 2007) Immediate (7 weeks after the incident) **Community (18–65 years)*** Exposed (N = 794) controls (N = 791)	Questionnaires of acute toxic and non-toxic symptoms HAD Scale	**Toxic symptoms** Toxic symptoms reporting was associated with oil exposure and with raised perceived risk

* Same population

Nakhodka (Japan, 1997)
Summary of Epidemiologic Study

Study characteristic	Exposure/Outcome	Results
Cross-sectional (Morita et al. 1999) Immediate **Cleanup workers (40-70 years)** Exposed (N=282)	Questionnaires	**Toxic symptoms** Primary symptoms reported were neurological, ocular(eyes) and upper respiratory symptoms **Physical injuries** Low back pain **PPE use** PPE use: gloves (100%), masks (women, 87%; men, 35%), glasses (<30%)
	Personal air samplers to measure benzene, toluene and xylene	**Exposure** Hydrocarbons levels in air significantly below occupational safety levels
	Urine toxicity levels	Unremarkable

Erika (France, 1999)
Summary of Epidemiologic Study

Study characteristics	Outcome	Results
Cross-sectional (Schvoerer et al, 2000) Immediate **Community including cleanup workers and volunteers** (N = 3,669)	Questionnaires and telephone interviews on acute symptoms	**Toxic symptoms** Neurological, dermal (skin), ocular (eyes) and respiratory symptoms **Physical injuries** Lumbar pain Duration of cleaning work identified as risk factor

Prestige (Spain, 2002)
Summary of Epidemiological Studies

Study characteristics	Exposure/Outcome	Results
Cross-sectional (Suarez et al. (2005)* Immediate **Cleanup workers (16+ years)** 133 seamen, 135 bird cleaners, 266 volunteers and 265 paid workers (N = 799)	Questionnaire on exposure conditions and acute health problems	**Toxic symptoms** Toxic effects higher among seamen compared to other groups **Injuries** Bird cleaners had highest occurrence of injuries (bruises, deep wounds, sprains, fractures etc.); working 20+ days in highly polluted areas associated with increased risk of injury
Cross-sectional (Carrasco et al. 2006)* Immediate **Cleanup workers (16+ years)** 133 seamen, 135 bird cleaners, 266 volunteers and 265 paid workers (N = 799)	Questionnaire on exposure conditions, acute health problems Use of personal protective equipment (PPE) and health-protection information received	**Toxic symptoms** Seamen, the most exposed group, had the highest frequency of symptoms **PPE use** Health-protection briefing associated with use of PPE Uninformed and worst-informed subjects (paid workers and seamen) had increased toxic symptoms

* Same population

Prestige (Spain, 2002) cont'd..

Study characteristics	Exposure/Outcome	Results
Cross-Sectional (Zock et al. 2007) 1 year after spill **Cleanup workers (17 – 80 years)** (N = 6780)	Questionnaires with qualitative and quantitative information on cleanup activities and respiratory symptoms	**Chronic symptoms** Risk of lower Respiratory tract symptoms (LRTS) increased with the number of exposed days, exposed hours per day and number of activities Excess risk of LRTS decreased with time

Prestige (Spain, 2002) cont'd..

Study characteristics	Exposure/Outcome	Results
Cross-sectional (Laffon et al. 2006) Immediate **Workers cleaning and conducting autopsies on birds (20-35 years)** Exposed (N = 34) Controls (N = 35)	Environmental VOC using passive diffusion sampling Genotoxicity biomarkers: Comet assay, SCE, MN test DNA repair genetic polymorphisms	**VOC exposure** Level of VOCs within the range observed in urban environments of low-contaminated cities Levels of benzene did not exceed threshold limit values **Genotoxicity** Exposed individuals had higher DNA damage, but not cytogenetic damage, related to time of exposure
Cross-sectional (Pérez-Cadahía et al. 2006) Immediate **Volunteers and cleanup workers (18-50 years)** 25 volunteers, 20 hired manual workers (MW) and 23 hired high-pressure workers (HPW) (N = 68) Controls (N = 42)	Environmental VOC using passive diffusion sampling Genotoxicity biomarkers: Comet assay, SCE, MN test	**VOC exposure** Highest VOC levels in volunteers' environment **Genotoxicity** Significant increase in comet assay in exposed individuals indicating genotoxic damage No effect of using protective mask during cleanup

Prestige (Spain, 2002) cont'd..

Study characteristics	Exposure/Outcome	Results
Cross-sectional (Pérez-Cadahía et al. 2007) Immediate **Volunteers and hired workers (18-50 years)** 25 volunteers, 20 MW and 23 HPW (N = 68) Controls (N = 42)	Environmental VOC using passive diffusion sampling Assessment of heavy metals in blood (Al, Cd, Ni, Pb, Zn) in peripheral blood Genotoxicity biomarkers: SCE, prolactin and cortisol levels Metabolic genetic polymorphisms	**VOC and heavy metals exposure** Highest VOC levels in the volunteer's environment Significant increase in the levels of Al, Ni and Pb, and decrease of Zn, in exposed individuals **Genotoxocity/endocrine** Significant increase in SCE rate in exposed, influenced by age, sex, smoking; significant decrease in prolactin and cortisol levels in exposed subjects
Cross-sectional (Pérez-Cadahía et al. 2008a) 3-4 months after study **Volunteers and cleanup workers (18-50 years)*** 61 volunteers, 59 MW and 60 HPW (N = 180) Controls (N = 60)	Assessment of heavy metals in blood (Al, Cd, Ni, Pb, Zn) in peripheral blood Genotoxicity biomarkers: Comet assay, SCE, MN test Hormone (prolactin and cortisol) Metabolic genetic polymorphisms	**VOC and heavy metals exposure** Significant increase in levels of Al, Ni and Pb, and decrease of Zn, in exposed group **Genotoxocity/endocrine** Significant increase in comet assay; decrease in cortisol levels in exposed group; higher DNA damage in the exposed groups

Prestige (Spain, 2002) cont'd..

Study characteristics	Exposure/ Outcome	Results
Cross-sectional (Pérez-Cadahía et al. 2008b) 3-4 months after study **Volunteers and cleanup workers (18-50 years)*** 61 volunteers, 59 MW and 60 HPW (N = 179)	Assessment of heavy metals in blood (Al, Cd, Ni, Pb, Zn) in peripheral blood samples Genotoxicity biomarkers: Comet assay, SCE, MN test. Hormone (prolactin and cortisol)	**Genotoxicity/endocrine** Pb was related to the comet assay. Cortisol plasma concentration influenced by Al and Ni inversely and by Cd positively. Strong association between Cd and prolactin levels
Cross-sectional (Pérez-Cadahía et al. 2008c) Immediate **Volunteers and cleanup workers (18-50 years)*** 59 volunteers, 53 MW and 47 HPW (N = 159) Controls (N = 60)	Genotoxic assessment of DNA: MN test Metabolic genetic polymorphisms DNA repair genetic polymorphisms	**Genotoxicity** Increases in MN frequency and decreases in the proliferation index observed in individuals with longer time of exposure
*Same population		

Tasman Spirit (Pakistan, 2003)
Summary of Epidemiological Studies

Study characteristics	Exposure/Outcome	Results
Cross-sectional (Janjua et al. 2006) Immediate **Residents (15+ years)** Exposed residents (N = 216) and controls living 1mile (N = 83) and 8 miles(N = 101) far from the coastline	Questionnaires	**Toxic symptoms** Moderate-to-strong associations between the exposed group and symptoms A trend of decreasing symptom-specific risk of symptoms with increase in distance from the spill site
Cross sectional (Khursid et. 2008) Immediate **Vendors/residents** Health symptoms of vendors working/living in the vicinity (N= 100)	Hematological and biochemical parameters Liver and renal function tests Hydrocarbon/organic content in seawater and sand samples	**Hematological, liver and renal function** Lymphocyte and eosinophil levels slightly elevated 11 persons had raised SGPT, not significant **Exposure** Seawater had no traces of hydrocarbon content

Tasman Spirit (Pakistan, 2003) cont'd..

Study characteristics	Outcome	Results
Cross sectional (Meo et al. 2009) Immediate **Cleanup workers** Male nonsmoking workers (N=50) and controls (N=50)	Toxic symptom questionnaire General health symptoms	**Toxic symptoms** Cleanup workers had a higher prevalence of ocular (eyes), respiratory and general symptoms compared to controls
Cross sectional (Meo et al. 2008) Immediate **Cleanup workers (27- 30 years)** Exposed (N=20) and controls (N=31)	Lung function: spirometry	**Lung function** Significant reduction in lung functions (FVC, FEV1, FEF25–75% and MVV) among cleanup workers Lung function parameters improved when subjects were withdrawn from the polluted environment

Conclusions: Exposure

- Hydrocarbons below occupational safety levels
- Level of VOCs within the range observed in urban environments; highest VOCs in volunteers' environment
- Level of benzene did not exceed threshold limit values

Conclusions: Toxic symptoms - Community (residents living in the vicinity of the oil spill)

- Consistent evidence of acute toxic effects (neurological, ocular, respiratory) among the community after adjustment of pre-existing allergic and medical conditions
  - Symptoms associated with exposure (living in the vicinity or volunteers)
- Biochemical tests for lung, kidney and liver function within normal limits; six months after oil spill similar finding
  - Children's respiratory function within the normal range

Conclusions: Toxic Symptoms – Cleanup Workers

- Consistent reporting of acute toxic symptoms (dermal, ocular, respiratory, neurological)
  - Duration of cleaning work was a risk factor
  - Seamen had the highest occurrence of toxic symptoms compared to volunteers or paid workers
  - Lower respiratory tract symptoms noted after one year associated with number of days worked and tasks/day
- Reduction in lung function was transient; improved when withdrawn from polluted environment

PPE use

- Less than optimal; health briefing increased use of PPE and reduction of symptoms
- Uninformed and poorly-informed workers were at more risk of exposure and symptoms

Conclusions: Injuries - Cleanup Workers

- Employment for more than 20 days was associated with increased risk of injures
- Bird cleaners had a higher frequency of injuries compared to other cleanup workers
- Cleanup and volunteer workers reported back pain

Conclusions: Genetic and Endocrine Toxicity

- MV Braer tanker spill: no genotoxicity noted
- Prestige tanker spill:
  - Volunteers doing bird cleaning/autopsies exhibited DNA damage, but not cytogenetic damage
  - Manual work volunteers had the highest level of VOCs compared to hired manual or hired high-pressure water machine workers; exposure associated with genotoxic damage strongly influenced by gender, age and smoking status but not by PPE use; alterations in hormonal status (prolactin and cortisol concentrations)
  - Increased levels of heavy metal exposure (aluminum, nickel and lead) associated with DNA damage and plasma prolactin concentration; several genetic polymorphisms in metabolizing enzymes and DNA repair proteins; use of PPEs had no effect
- Long-term studies are needed to clarify potential genotoxic and endocrine changes

Limitations

- Most studies were at a point in time (cross-sectional); cannot establish a temporal relationship between exposure and outcome
- A few studies had no comparison groups limiting interpretations
- Some studies were small in size
- Potential for information/publicity bias in reporting illness occurrence
- Low participation (eg. MV Braer)

Limitations - cont'd..

- Dependence on surrogate estimates of exposure (distance from oil spill or living in the vicinity)
- Inability to develop useful dose-response data
- Biomonitoring (exposure/outcome) – limited and at one point in time
- No long-term follow-up of high-risk groups for exposure and/or outcome assessment

Thank You