# ROLE OF FORENSIC MEDICINE IN DIAGNOSING ACCIDENTAL OCCUPATIONAL POISONING

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***Keywords:*** *accidental exposure, forensic toxicology, mixtures, poisoning, workplace*

***Abstract:*** *Objective: this study aimed to establish the importance of dose-response relationship for a rational diagnosis of acute poisoning with chemical mixtures. Methods: data regarding unintentional exposure, circumstances, medical and toxicological information were collected from 21 cases with acute intoxication as a consequence of three different accidents at work, investigated and registered as occupational disease. Results: organic solvents were the main identified components of unintentional mixtures responsible for poisoning and possible long-term health effects in the workers of concern, but interactions of chemicals were difficult to assess, in the absence of sufficient human evidence. Conclusions: causality and diagnosis relied on forensic toxicology whose close relationship with occupational medicine may be useful in designing new models of risk assessment for occupational health and safety managers.*

## INTRODUCTION

Chemical mixtures, respectively "sets of multiple chemicals regardless of source that may or may not be identifiable that may contribute to joint toxicity in a target population", are one of the toxicology's huge unknowns.(1) Clinical symptoms may occur when at least one component of the mixture is a lipophile and at least one other component of the mixture is a hydrophile.(2) From the perspective of forensic medicine, practitioners of occupational medicine must take into account the epidemiology of disease and occupational hazards in establishing causality and diagnosis, as well as close knowledge of relevant laws.(3) According to Romanian Regulations (4), the main purpose of reporting work-related incidences (accident and occupational disease) is for the public health authority to determine the underlying causes of the incidences in order for remedial actions to be taken to prevent similar occurrences in the future and, at the same time, to form important database to carry out analysis and to come out with strategic plan to administer and enforce the law. Recordable occupational injuries/poisonings/diseases result in either fatalities and lost workday cases other than fatalities, or non-fatal cases without lost workdays. From the perspective of Romanian Law, a work-related accident is regarded as a particular type of event in which an injury or illness actually occurs with a certain frequency and severity of consequences. The consequences on worker's health can be classified under medical criteria as temporary work disablement, invalidity and decease, and may vary in terms of severity from negligible to maximal consequences.(5) Where the accidents involve at least three workers at the same time they are referred to as collective accidents.

Currently, there is a gap between medical and forensic medical knowledge when investigating collective occupational poisoning as a consequence of unusual and unintentional exposure to chemical mixtures. In this respect, some authors suggest the integration of forensic nursing in workplace investigations.(6) Generally, legal aspects of occupational toxicants are related to workers' compensation, unusual requests, and accidents.

Because of limitations in the scientific evidence surpassed by the introduction of new chemicals in industrial processes, continuous investigation is required. The list of chemical-induced occupational diseases should expand from anatomical classification system to criteria for the recognition of acute poisoning (symptoms and signs), and to newly recognized hazardous chemicals related to occupational disease using epidemiologic studies.(7) Long-term effects should also be considered, especially for neurotoxicants and carcinogens like mixtures of organic solvents. For example, chronic solvent encephalopathy is under-reported worldwide, although it can be detected using screening tests.(8)

Romanian statistics on occupational intoxications show an increasing trend of acute poisoning starting in 2015 with 82.8% cases due to accidental exposure to organic solvents(9), and continuing in 2016 with 100% cases of all reported poisonings, due to accidental exposure to volatile toxicants.(10) This might be a situation of concern, and acute exposures should be taken into account as a realistic scenario for prospective risk assessment following the precautionary principle.

## PURPOSE

For the purpose of this paper, data regarding workers who suffered acute intoxication due to unintentional chemical mixtures were extracted and briefly described in terms of causality and rational diagnostic strategy.

## MATERIALS AND METHODS

Data sources were obtained from local public health authority records as follow:

**Registry book of occupational diseases.** Individual data were collected from 21 cases with occupational acute poisoning due to three collective accidents at work in the period 2004-2016. All these workers were accidentally exposed to chemical mixtures *via* inhalation in three different enterprises from Sibiu County.

**Occupational disease investigation files,** which included: occupational exposure history; identified/measured concentration of chemical hazards; identification-form of occupational risks; medical documents supporting the diagnosis

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(hospital discharge cards, medical certificates, and toxicological reports); minutes of investigation the case of occupational poisoning; and reporting-form of occupational disease. Occupational acute poisoning is investigated, adjudged and registered both as an occupational disease, as well as an accident at work, according to Romanian Law.(4) Toxicological reports, respectively medico-legal report in one fatal case, were provided by the Legal Medicine Service following the public health authority's request.

Air investigation in the workplace was performed by the public health authority using the Dräger-Tube measurement system (colorimetric chemical sensors) for identification and on-the-spot measurement of gaseous air contaminants (11); and using the real time dust monitor Casella for the detection and gravimetric measurement of airborne dusts, fumes and aerosols in the range of occupational exposure limits given in Table 1.

**Table no. 1. Limit values of identified chemicals, according to Romanian Regulation (12)**

| Substance | TLV-TWA* (mg/m$^3$ air) |
|---|---|
| Acrylonitrile | 5 |
| Aliphatic hydrocarbons | 700 |
| Ammonia | 14 |
| Carbon black powder | 2 |
| Formaldehyde | 1.2 |
| Tetrachloroethylene | 50 |
| Trichloroethylene | 100 |
| Vinyl chloride | 7.7 |
| * threshold limit value – time-weighted average (for 8-hour workday) | |

Details have been removed from these case descriptions to ensure anonymity. As investigation and reporting of occupational diseases to the National Operative Registry is compulsory by law (active since 1964, updated in 2004) ethics approval is not required.

## RESULTS

General characteristics of the subjects are given in table no. 2. Most of the victims were young females (86%) with limited health consequences requiring medical treatment and sick leaves for lost workdays between 3 and 25. Maximal consequence (decease) occurred in 2012, when the youngest of the three machinists suffered a fatal accident due to severe intoxication. Dizziness and nausea with or without vomiting were the most common clinical symptoms, followed by upper respiratory tract irritant syndrome. In addition, narcotic syndrome, hepatotoxic syndrome, hypotension and mydriasis occurred in workers poisoned in 2004.

The investigation files were well-documented with respect to: air measurements of volatile and particulate substances in the workplaces of concern, respectively formulated product testing - in 2004; detailed description of circumstances and technological processes; types of mixtures (formulated product marketed as such and its safety data sheet - in 2004 and 2012, or mixtures generated by discharge during production - in 2016); hospital records from Emergency Room and Clinic; sick leave certificates; and forensic toxicological report. In summary, results are presented in tables no. 3 and 4.

**Table no. 2. Age, Seniority, Gender, Occupation, and the number of Occupational Poisoning Cases and Lost Workdays in work-related accident victims**

| Date of collective accident at work (year) | Occupation | Gender | Age (years) | Seniority (years) | Acute occupational poisoning (no. of cases) | Lost workdays per person(average) |
|---|---|---|---|---|---|---|
| 2004 | confectioners | females | 25±7.8 | 3±2.3 | 8 | 18 |
| 2012 | machinists | males | 44±22.5 | 13±20.9 | 3 | 5 |
| 2016 | assemblers | females | 38±12.6 | 4±3.1 | 10 | 11.4 |

**Table no. 3. Circumstances and chemical risk assessment for the three industrial accidents**

| Date of accident (year) | Industrial activity / circumstances | Measurements | |
|---|---|---|---|
| | | Air-identified substance* (mg/m$^3$ air) | Product-identified composition** |
| 2004 | Floor cleaning in the production department / large evaporating surface | - | Ethoxyethanol;<br>Trimethyl hexanoic acid;<br>Esters of propanoic acid;<br>Stearyl alcohol;<br>Aliphatic hydrocarbons ≥ $C_{10}$;<br>Tributoxyethyl phosphate |
| 2012 | Degreasing of metal parts in quasi-confined space / lack of ventilation | Trichloroethylene (97.2)<br>Tetrachloroethylene (49.2)<br>Aliphatic hydrocarbons (237) | - |
| 2016 | Plastic injection molding / uncontrolled high temperature | Formaldehyde (0.2)<br>Vinyl chloride (2)<br>Ammonia (7.1)<br>Acrylonitrile (1.2)<br>Carbon black powder (1.8) | - |
| * Performed by Public Health Authority 3-4 hours after the accident<br>** Performed by Legal Medicine Service | | | |

**Table no. 4. Forensic toxicology-based diagnosis of occupational poisoning**

| Date of accident (year) | No. of cases | Diagnosis | Toxicological report | | |
|---|---|---|---|---|---|
| | | | blood | urine | method |
| 2004 | 8 | Acute intoxication with organic solvents | - | Trimethylhexanoic acid;<br>Esters of propanoic acid; Polyethylene glycols; Chlorinated polyethylene glycol derivatives | Gas chromatography - mass spectrometry (GC-MS) |
| 2012 | 3<br>(one fatal) | Acute intoxication with trichloroethylene | - | Halogenated aliphatic hydrocarbons | Fujiwara reaction-positive substances |
| 2016 | 10 | Acute intoxication with xylene and formaldehyde | Xylene; Formaldehyde | - | GC-MS;<br>Chromotropic acid procedure |

Products used in 2004 (liquid impregnating agent for floor polish) and in 2016 (solid pellets for injection molding) were defined as "mixture" for the chemical range of polymers; while product used in 2012 (liquid degreaser) was labeled as solvent containing trichloroethylene. According to the manufacturer, composition of the two mixtures was as follows: product responsible for 2004 poisoning contained polyacrylate, natrium benzoate, diethylene glycol monoethyl ether, and tributoxyethyl phosphate; product responsible for 2016 poisoning contained polyoxymethylene copolymer which could release formaldehyde at 150°C.

## DISCUSSIONS

In the hereby described accidental exposures to chemical mixtures the diagnosis relied on toxicological component-based approach (dose-response information), in the absence of sufficient information on the mode of action of some mixture components, i.e. trimethyl hexanoic acid, or esters of propanoic acid. Interactions of chemicals in mixtures - including antagonism, potentiation, and synergies - which usually occur at medium or high dose levels are generally more difficult to assess and require expert judgement on a case-by-case basis.(13) A rational diagnostic strategy could not be entirely achieved via screening methods currently provided by clinical and occupational toxicology. Occupational circumstances in relationship with Justice and lethal doses of toxicants need confirmation tests performed only by chromatographic technology coupled with mass spectrometry, which are sophisticated, extremely expensive, and require highly specialized personnel.(14) Due to GC-MS device owned by Legal Medicine Service, xylene was identified in workers' blood (2016 accident), while polyethylene glycols and their derivatives were identified in workers' urine (2004 accident). Usually, the diagnosis of acute xylene poisoning following its inhalation is suggested by urinary methylhippuric acid as a biomarker of exposure.(15)

Acute intoxication with trichloroethylene may cause the death of the subjects, usually determined by cardiac arrhythmia, pulmonary edema, or brain damage.(16) Due to the toxic multi-organ damages subsequently confirmed by the medico-legal report, one of the three workers involved in the 2012 accident died at the intensive care unit admission.

These worker groups may be considered vulnerable to work-related cancer in the future, since trichloroethylene, tetrachloroethylene, formaldehyde, vinyl chloride, xylene and carbon black are carcinogens.(17) Moreover, xylene, trichloroethylene, and tetrachloroethylene are neurotoxicants on the basis of sufficient evidence from humans.(18)

Several particularities of these accidents at work can be discussed, namely: the formulated commercial product used in 2004 for floor cleaning was not labeled as "harmful"; indoor air pollution was favored by inadequate ventilation; clinical symptoms and signs were difficult to differentiate from other types of poisonings, with the exception of upper respiratory tract irritant effects of formaldehyde and ammonia; and health effects were more significant in the 2004 accident, in terms of lost workdays and long recovery - more details are given in a previous publication (19) - possibly due to interaction of chemicals, but this remain an uncertainty. We assume for unacceptable air concentrations of chemical exposure which does not reflect those measured several hours after ventilation and evacuation of workers. Xylene might come from products used in the dye works next to the injection molding section.

Given a lack of regulatory requirement, as well as a limited availability of case examples, every step for additional advancement in chemical risk assessment of exposure to unintentional mixtures is of great interest (20) and may also contribute to the appropriate use of scientific evidence in the determination of compensability.(21) Complexity, magnitude, and uncertainty of the risk may help decision makers understand when and if there is enough evidence to act following a precautionary approach.(22)

## CONCLUSIONS

In conclusion, forensic toxicology is crucial for establishing dose-response relationship in occupational exposure to unintentional mixtures of toxicants and subject of further review of risk assessment and safety regulations in a broader manner.

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