

## Identifikacija opasne lokacije u urbanom području

Sonja Ketin<sup>1</sup>, Boban Kostic<sup>1,2</sup>

<sup>1</sup>University Business Academy in Novi Sad, Faculty of Economics and Engineering Management in Novi Sad, Cvećarska 2, 21 000 Novi Sad, Serbia

<sup>1,2</sup>Ministry of Agriculture, Forestry and Water Management, Nemanjina 22-26, Belgrade, Serbia

**Apstrakt:** U radu je prikazana identifikacija opasnih lokacija u slučaju iznenadnog ispuštanja opasnih hemikalija. U akcidentnim situacijama rizik se procenjuje na osnovu različitih metoda i utvrđuje akcioni plan koji ima za cilj minimiziranje rizika. Analizirane su akcidentne situacije u kojima je PCB i dioksin prosut u velikim količinama. U radu su korišćene metodologije Svetske zdravstvene organizacije, američke EPA i Ujedinjenih nacija. Na mapi su prikazane najvažnije detektovane lokacije u urbanoj sredini.

**Ključne reči:** akcident, opasna lokacija, hemikalija, rizik

## Identification of Hazardous Location in Urban Area

**Abstract:** The paper presents the identification of hazardous locations in the event of a sudden release of hazardous chemicals. In accident situations, the risk is assessed on the basis of various methods and an action plan is determined which aims to minimize the risk. Accident situations in which PCB and Dioxin was spilled in large quantities were analyzed. The methodologies of the World Health Organization, the American EPA and the United Nations were used in the paper. The most important detected locations in the urban environment are presented on the map.

**Key words:** accident, hazardous location, chemical, risk

### 1. Introduction

#### Chemical accidents

Chemical accidents and management of the assessed accident occurrence risk present an important aspect in the environmental protection. Accident, as defined by the European Union, presents a sudden appearance of considerable emission, fire or explosion as a result of not planned events within a certain industrial activity, occurring within or out of industry, including one or more chemicals (Mihajlov, 2001).

International Labour Organisation (ILO) statistics show that the highest percentage of accidents occurs in the production units (40%), in transport of hazardous substances (35%) and in storage (25%). According to the research that included 1.045 accidents with injured and killed people, in majority of cases it was the accidents with chlorine (125 cases), with hydrochloric acid (68 cases) and ammonia (67 cases). Oil and oil products have not been included in this research. International Labour Organisation has published the data from 40 member countries on the frequency of the appearance of certain chemicals in bigger chemical accidents in the past 80 years (Table 1).

Table 1. Frequency of appearance of certain chemicals in bigger accidents in 40 countries

	Chemicals	No. accident
1.	Natural gas, propane/butane	188
2.	Chlorine	123
3.	Petroleum naphtha	68
4.	Ammonia and compound	62
5.	Vinyl chloride	41
6.	Chlorohydric acid	32
7.	Hydrogen	30
8.	Sulphuric acid	23
9.	Ethylene	21
10.	Ethylene oxide	18

Approximately 70% of the accidents described by US EPA took place in the plants, while the remaining 30% occurred during the transport of toxic chemicals.

National legal document that defines the risk assessing methodology is «Regulations for the Methodology of Chemical Accident and Environmental Pollution Risk Assessment, by Measures of Preparation and Measures of Consequence Elimination, *Official Gazette of the Republic of Serbia*, No. 60/1994, 63/1994».

The following are defined as the consequences of chemical accidents:

- discharge of hazardous pollutants into the air, water or soil (toxic gases, flammable or explosive substances);
- explosion of matter that creates destructive wave blow (significant input of great quantities of toxic, flammable and explosive matter is discharged into the atmosphere);
- fires creating heat radiation that might burn people and material property (cloud of hazardous and non-hazardous gases, particles and other combustion products is formed);
- combination of the previously mentioned consequences.

Persistent organic pollutants (according to the Stockholm Convention POPs) are particularly important due to their specific properties.

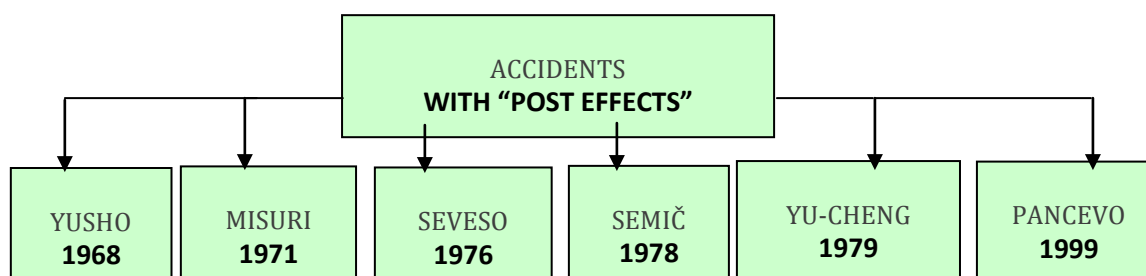


Figure 1. Schematic presentation of the known accidents with «post effect»

**ACCIDENT YUSHO:** The first reported accident related to the toxicity of polychlorated biphenyls took place in Japan in 1968 (Yusho), where these compounds were used as the cooling fluid in the rice oil production. Leakage or an error in the system occurred thus causing the rice oil to be uncontrollably contaminated with polychlorated biphenyls. This contamination caused in the consumers diseases with hyperpigmentation of the skin and mucous membrane, liver diseases, headache, nausea, edema and birth of children with defects. However, laboratory analyses showed that PCB caused hepatocellular cancer in experimental animals. Exposure to polychlorated biphenyls is practically universal in industrial countries. Due to chemical stability and liposolubility, polychlorated biphenyls are bioaccumulated and biomagnified through food chain. High level of concentration was found in fish, because of the discharge of transformer oil into the river. The total number of contaminated patients in Yushu was 1862, and about 149 people died.

**ACCIDENT MISURI:** «Shenandoah Stables» was a big horse ranch in the state of Missouri. Their problems started in 1971. In order to reduce the quantities of dust, they covered several acres with 1000

gallons of waste automobile oil. Soon there were tens of dead sparrows to be found. Afterwards, cats and dogs on the farm got sick. Of 85 horses, 43 died in the course of one year. Most of the horses had miscarriages. Animals born at the time would die after only a few months. The owner and his two daughters also got sick. Upon testing of the oil that had been sprinkled over the farm, a high level of dioxins and polychlorated biphenyls was established. Many similar cases were discovered.

**ACCIDENT SEVESO:** Accident in Seves happened in 1976 in the chemical plant for the production of pesticides and herbicides. Toxic cloud contained tetrachlorodibenzoparadioxin (TCDD) that had been released from the reactor for the production of trichlorophenol. Dioxins were formed as by-products of uncontrolled exothermic reactions.

At that time, there were more than 600 people evacuated from their houses and more than 2000 people were contaminated with dioxins. As a response to this heavy accident, SEVESO I and SEVESO II Directives ensued.

**ACCIDENT SEMIČ:** On the territory of former Yugoslavia in Semič (Slovenia), an accident occurred in 1978. PCB was discharged from the condenser producing factory into the river. The study analysing the effect of PCB on human population established that there was a more rapid growth of teeth in children.

**ACCIDENT YU-CHENG:** Omnipresence and slyness of the pollution by polychlorated biphenyls is illustrated in the following accident that took place in 1979 in Thailand. An unused transformer in a slaughterhouse had accidentally been punctured. Polychlorated biphenyls were released and they entered the fat and meat waste recycling system. The obtained product was sold as chicken feed to a big farm. In the following few months, eggs were sold and used by bakers and mayonnaise producers. When contamination was discovered, food all over the country, worth millions of dollars, was withdrawn from the market and destroyed. Later research showed that Yu-chang consequences were serious changes in the development of mobility and memory in children. There were 2008 contaminated people registered in Taiwan. Further research showed that the consequences of the accident in Taiwan were more serious than those of Seveso accident.

**ACCIDENT PANCEVO:** In 1999, there was a war accident in Pančevo. Namely, there was a big explosion of vinyl chloride monomer and consequently a cloud was formed of unreacted vinyl chloride monomer, phosgene and other chlorine products (Bančov, 2004).

According to some research, by analysing the combustion product samples taken directly above the flame of vinyl chloride monomer burning in the air, the presence of following was discovered: HCl (2,7%), CO<sub>2</sub> (5,8%), CO (0,95%) and phosgene <10 ppm. Significant quantities of phosgene were present only in the immediate vicinity of vinyl chloride monomer flame. Just as in Seveso accident, there were no casualties at the time of the accident, but there were post effect diseases in people who had been exposed to carcinogenic substances. Vinyl chloride monomer is a carcinogenic, teratogenic and mutagenic substance that, when burnt, forms phosgene, a known war (poison) gas and other combustion products of which dioxin is particularly singled out. The effects of dioxin were detected and registered in Seveso accident. Bearing in mind the Seveso accident experience, European Union Directives SEVESO I and II must be applied, as well as the existing national legal regulations for the preparation of the Chemical Accident Protection Plan, which must define preventive measures and chemical accident response measures. The Plan is being prepared on the local level, based on the prepared assessment of the chemical accident hazard for the companies that might cause heavy chemical accidents. The companies categorised as extremely high-risk companies are obligated to prepare the chemical accident hazard assessment and to verify this document with the Ministry competent for the environmental protection.

## 2. Methods and Methodology

### Dioxin formation mechanism

Since dioxins belong to I group carcinogens, the paper presents the mechanism of dioxin formation (Figure 2).

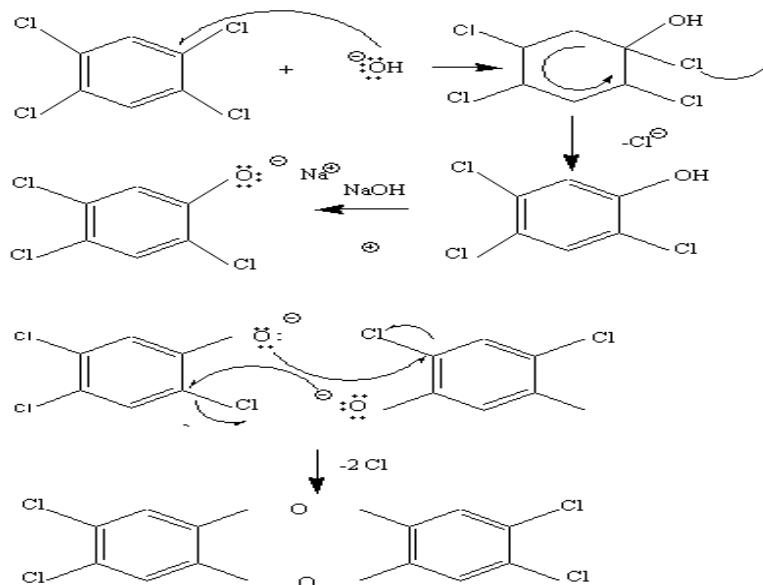


Figure 2. Presentation of dioxin formation mechanism

### Solution of environmental problems

For the purpose of prevention and the best possible response in chemical accident situations, cooperation with the Italian Environmental Protection Ministry was initiated resulting in an agreement to apply a new methodology for the chemical accident hazard assessment (REHRA) developed by the World Health Organisation (WHO). The Programme has been implemented in Italy, Hungary, Romania and Bulgaria. The advantage of this Programme is a quick anticipation of possible accident points in a plant.

Preparation for implementation of the new methodology in oil-petrochemical complex in Pančevo is underway.

### Monitoring system for air quality control

Monitoring system located in Pančevo industrial zone, parts of Pančevo town, and in Pančevo Municipality building has the following objectives:

- Hazardous substance concentration monitoring
- Automatic exchange of meteorological data
- Assessment of hazard degree for the population in cases of regular plant operation or in cases of chemical accidents on the industrial zone

The necessary input data that can be read from the automatic meteorological station are: temperature ( $^{\circ}\text{C}$ ), relative air humidity (%), air pressure (mbar), global and Sun radiation balance ( $\text{W}/\text{m}^2$ ), wind velocity (m/s) and wind direction ( $^{\circ}$ ).

Hazardous substance data base is also required, containing the following elements: chemical element, formula, physical-chemical properties, concentration level per hazard class, synonyms, flammability.

Air monitoring implies imission measurement in compliance with the Air Control Programme passed by the Government every 2 years.

The objectives of the Air Quality Control Programme are as follows:

- Determining the air pollution level
- Monitoring the air pollution trends over several years
- Air quality assessment based on comparisons with the standards
- Establishing remedial measures for the purpose of improving the air quality

- Establishing critical situations and alarming states for the purpose of warning the public and taking the necessary measures.
- Assessment of the polluted air impact on public health, climate and forest ecosystem.

Air Quality Control Programme examines the essential (group of pollutants widely spread and inevitably present in every-day human activities) and specific pollutants (group of pollutants emitted from specific industrial production processes).

Air quality control is achieved by systematic imission measuring, monitoring and analysing the air quality effect on the environment and by reporting the results of this measuring, monitoring and analysing. Network of measuring points was established based on the international model (World Meteorological Organisation (WMO) and World Health Organisation (WHO)). The number of measuring points comprised in the monitoring network is determined on the basis of the following criteria: number of inhabitants, number of emission sources and meteorological parametres.

### **Selection of risk assessment methodology**

#### **National methodology**

National risk-management strategy has three basic parts:

- Accident hazard analysis.
- Planning the preventive measures, preparedness and response to an accident.
- Planning the accident consequence elimination (remediation).

Accident hazard analysis includes:

- Identification of hazard (preparation, data collecting, identification and change of identification).
- Consequence analysis (preparation, presentation of a possible course of events, effect modelling and analysis of vulnerability).
- Risk assessment (assessment of accident occurrence probability, assessment of possible consequences and risk assessment).

Planning the preventive measures, preparedness and response to an accident includes:

- Prevention (prevention measures and actions).
- Preparedness (accident protection plan).
- Response to an accident (time and place of accident, type of harmful substances present, accident course assessment, environmental risk assessment and other information important for responding to an accident).

Planning the accident consequence elimination measures (remediation) includes:

- Remediation plan (remediation objectives and scope, remediation task force and means, order of application, programme of post-study environmental monitoring, remediation costs, the manner of informing the public about the past accident).
- Report on the accident (analysis of the accident causes and effects, accident development and course and response to accident, accident magnitude assessment and present situation analysis).

#### **Current world methodologies**

There are several current world methodologies:

- REHRA Methodology was developed by the World Health Organisation (WHO).
- US EPA Methodology was developed by the American Environmental Protection Agency (EPA).
- APELL Methodology was developed by the United Nations Environment Programme (UNEP).

**REHRA** (Rapid Environment and Health Risk Assessment) has been implemented in Italy, Hungary, Romania and Bulgaria. Legal acts used in the preparation of this methodology were as follows: SEVESO II Directive, Helsinki Declaration from 1992 and Espoo Convention.

Three basic parts of REHRA Methodology are as follows:

- risk assessment of big accidents.
- continuous emissions risk.
- territory hazard.

Indexes used in the risk assessment calculation according to REHRA Methodology are as follows: Installation Hazard Index (IHI), Accident Risk Index (ARI), Installation Risk Index (IRI), Equipment Risk Index (ERI).

**US EPA** (United States Environmental Protection Agency)

This Methodology includes several softwares:

- **CAMEO** (Computer-Aided Management of Emergency Operation) is an accident-management programme. It contains a library and chemical substances base, examines accident situations, locations, etc.
- **ALOHA** (Area Locations of Hazardous Atmospheres) is a programme for harmful gases dispersion modelling.
- **MARPLOT** (Mapping Applications for Response, Planning and Operational Task) is a programme for electronic presentation of a certain location.

**APELL** Programme (Awareness and Preparedness for Emergencies at a Local Level) is implemented within UNEP. A significant characteristic of this programme is distribution of responsibility for planning and implementing the chemical accident protection measures among industry, local management, professional organisations, state agencies and the public. In order to ensure a direct and close cooperation, as well as unique approach and trust among the participants in responding to an accident, **APELL** anticipates formation of local coordination groups, as a bridge between industry and local community.

### 3. Results and Discussion

#### Presentig risk assessmnet in Serbia

Project «**Environmental Atlas of Belgrade**» has recently been completed and, in addition to other environmental issues, it has also analysed hazardous industries, plants and accident risks. Transport, chemical industry, storage and the list of all hazardous substances with quantities have been analysed. On the territory of Belgrade, there are tens of hazardous industries and plants that use, store or produce hazardous substances. Some of them are located in the very centre of the city (Duga, Galenika, Jugopetrol-Čukarica and others). Chemical accidents and fires on these locations would present considerable danger for the residential areas in the vicinity of which these facilities are located. According to the identification of industrial hazards on Belgrade territory from 1990, there were 69 hazardous industries registered that produce, use and store hazardous substances. According to the same source, about 1.250.000 tons of hazardous substances were used, produced or stored yearly in the city, of which 15.000 tons presented harmful waste. Furthermore, the risk of possible chemical accidents in numerous new chemical plants of the small private companies is considerable and not fully identified as yet. These plants are located in residential areas both in marginal and in some central parts of the city. The public is further jeopardised by huge chemical complexes in Pančevo and Barič, which, due to their vicinity, present a significant, still not quantified threat to certain parts of Belgrade (Sacirovic, et al. 2019). From Pančevo industrial zone, as shown by the spreading of contaminated air during the bombing of Petrochemical Complex, as well as by spreading of pollution in the peacetime, possible chemical accidents would present most threat to the north-eastern parts of Palilula municipality, while Barič complex presents most threat in terms of possible chemical accidents to the south-western parts of Čukarica municipality. According to the preliminary assessment of chemical accident risk, all hazardous plants, as identified at the time, were distributed into four risk groups. In the city general plan area, there was not a single plant of extremely high chemical risk, but even today,

there are five plants of high chemical risk (Duga, Galenika, Tehnogas, «Belgrade» Refinery, Jugopetrol-Čukarica), as well as 12 plants that have been assessed as medium-risk units. Today there are no updated and complete records of hazardous substances present in Belgrade, although this is required by the law. Based on the available information, identification and classification of hazardous industries was repeated, and a list of present locations with hazardous substances was made. For these facilities and locations, approximate chemical accident risk assessment and new categorisation of the facilities were carried out, and zones of possible effect were determined. In the city area, in the period 1991-2000, there were about 80 chemical accidents, half of which occurred during the transport of hazardous substances. That is why the question of safe transport of hazardous substances is extremely important, particularly the roads on which greater quantities of these substances are transported. Hazardous substances are transported by way of road, railway and river traffic (Ecoatlas Zdravlje, n.d.).

Table 2. Identification of hazardous industries and locations (Ecoatlas Zdravlje, n.d.).

	<b>Company</b>	<b>Location</b>	<b>Matter</b>	<b>The class</b>	<b>Type of transport</b>
1	Duga	Viline vode	organic solvents	<b>II</b>	railway
2	Galenika	Batajniki drum	organic solvents	<b>II</b>	road
3	Dalija	Batajniki drum	organic solvents	<b>II</b>	road
4	Grmec	Autoput, Zemun	organic solvents	<b>II</b>	road
5	Rekord	Rakovica	organic solvents	<b>II</b>	road
6	Rafinerija-Beograd	Pancevacki put	petroleum products	<b>III</b>	road
7	Jugopetrol	Radnicka	petroleum products	<b>III</b>	road, river
8	Beopetrol	Savska, Ostruznica	petroleum products	<b>III</b>	road
9	Tehnogas	R.Vujovica - Čoce, Rakovica	technical gases	<b>III</b>	road
10	Petrolgas	Ovca	butane-propane mixture	<b>III</b>	railway
11	Grmec-Balkan	Pancevacki put	organic solvents	<b>II</b>	road
12	Secerana - Vrenje	Radnicka	ammonia	<b>I</b>	railway
13	Tehnohemija	Viline vode	various chemicals	<b>II</b>	railway
14	Belgrade waterworks	Makic	chlorine	<b>I</b>	road
15	Belgrade waterworks	Bezanija	chlorine	<b>I</b>	road
16	Belgrade waterworks	Banovo Brdo	chlorine	<b>I</b>	road
17	BIP	Autoput, Beograd	ammonia	<b>I</b>	road
18	Hempro	Autoput, Zemun	various chemicals	<b>II</b>	road
19	Railway station Dunav	Viline vode	various chemicals	<b>II</b>	railway
20	Railway station Bgd	Savski most	various chemicals	<b>II</b>	railway
21	Railway station Ovca	Ovca	various chemicals	<b>II</b>	railway
22	Railway station Zemun	Zemun	various chemicals	<b>II</b>	railway

Substance class **I** - very toxic substances

Substance class **II** - toxic substances

Class of substance **III** - flammable substances

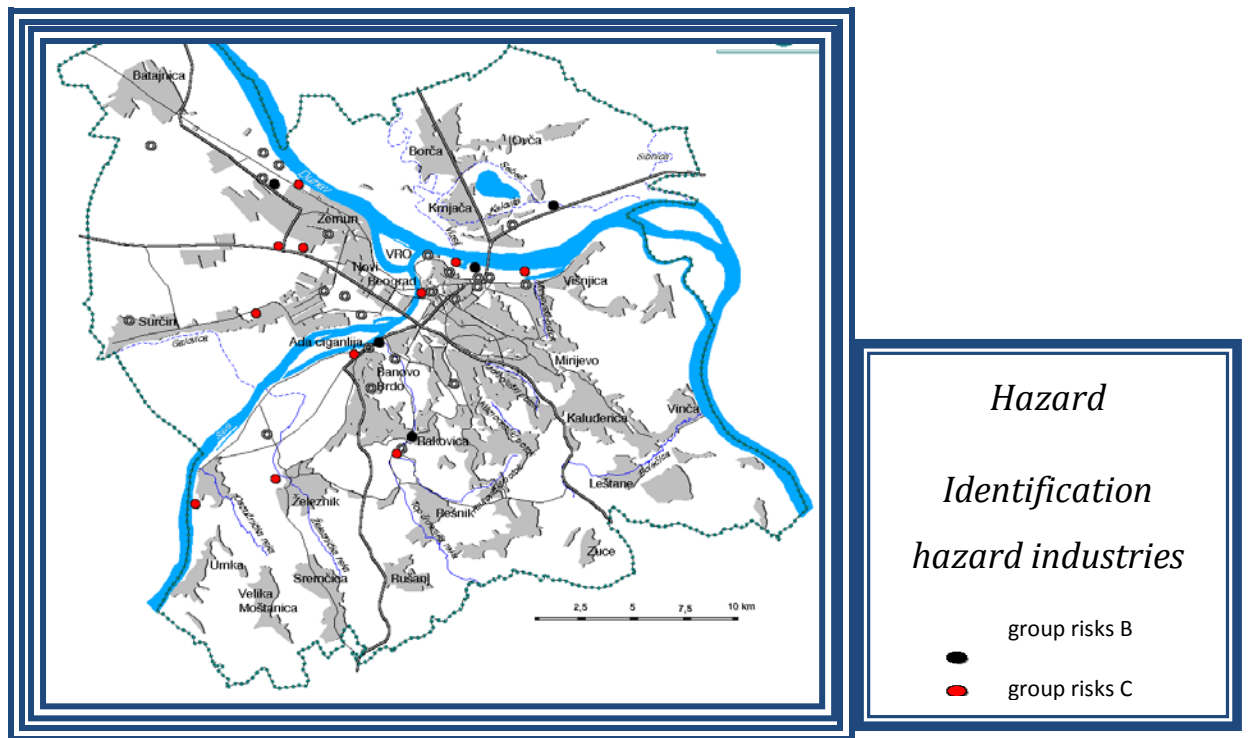


Figure 3. Identification of hazardous products - Ecological atlas of Belgrade (Ecoatlas Zdravlje, n.d.).

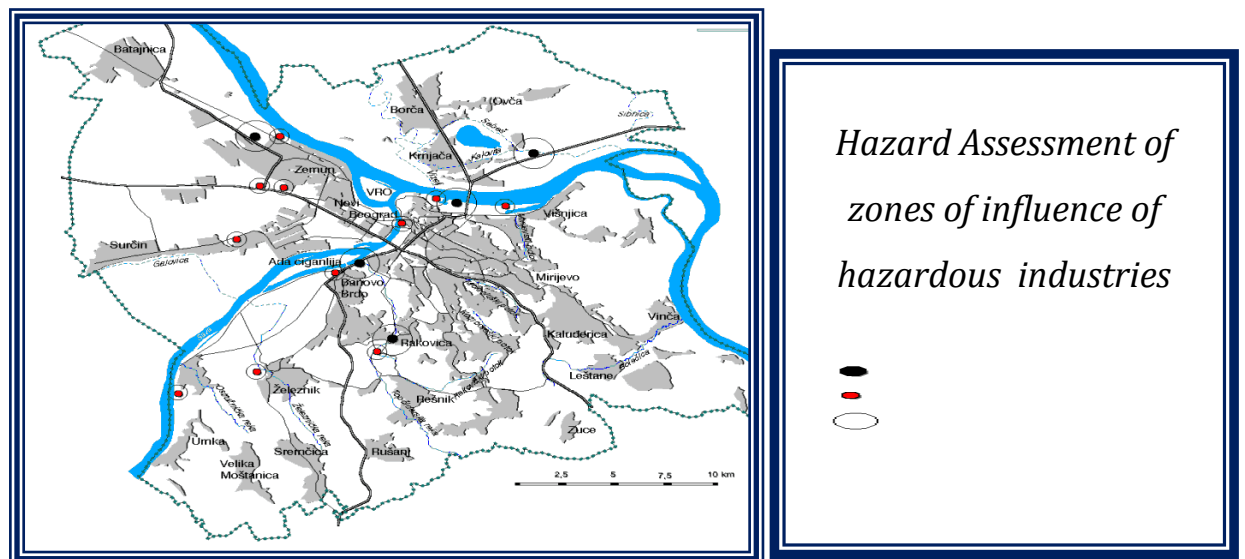


Figure 4. Evaluation of the impact of hazardous zones Industry (Ecoatlas Zdravlje, n.d.).



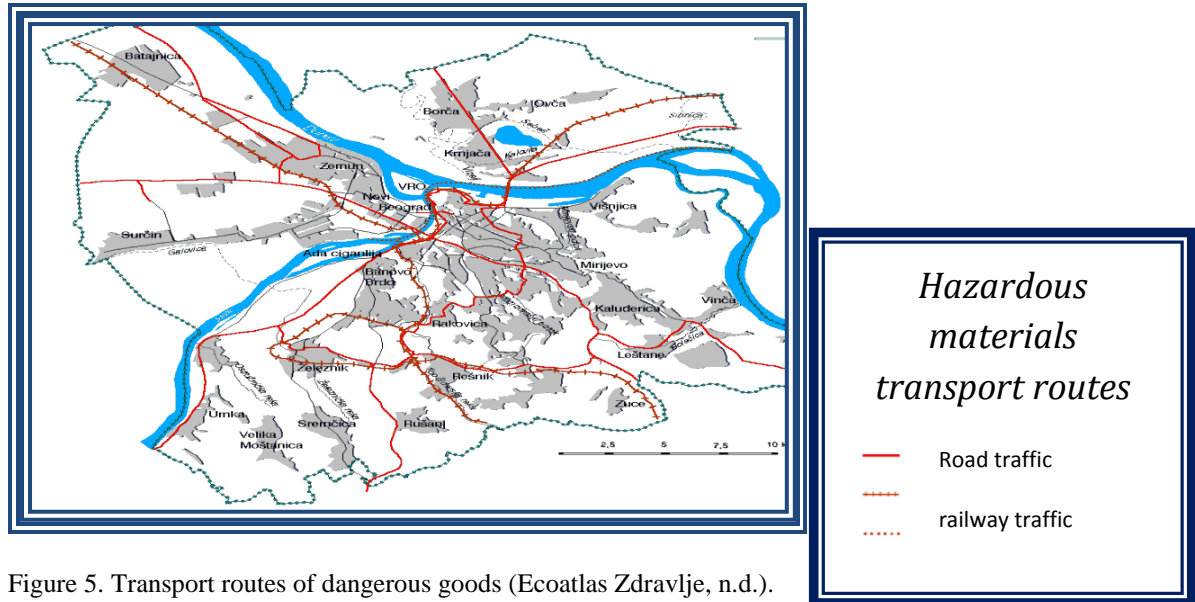


Figure 5. Transport routes of dangerous goods (EcoAtlas Zdravlje, n.d.).

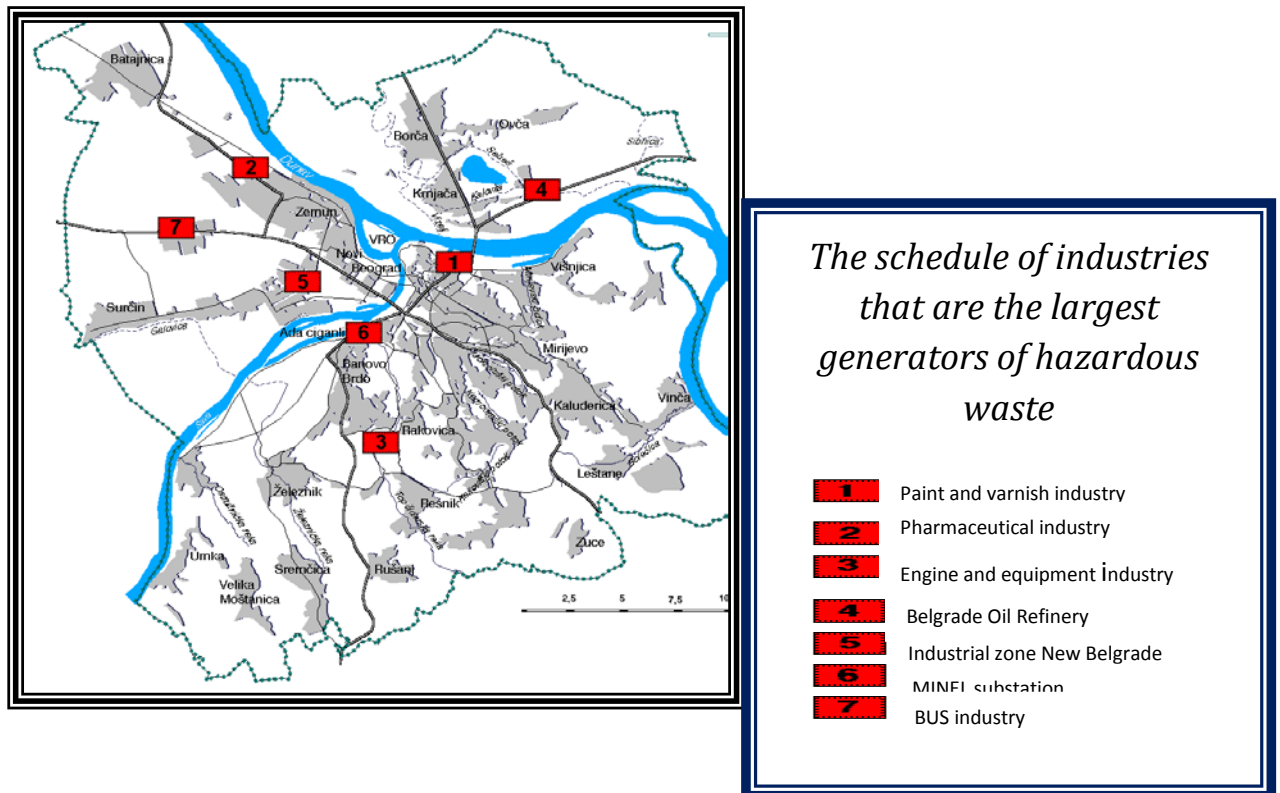


Figure 6. The schedule of industries that are the largest generators of hazardous waste (EcoAtlas Zdravlje, n.d.).

## Conclusion

Upon analysing the comparative models for the assessment of chemical accident risk, it can be concluded that the experiences from the accidents in Yusho (Japan), YU-chang (Taiwan), Seveso (Italy), and in many other places, can be applied in the solution of environmental problems in Pančevo. Chemical accidents are particularly important in analysing the post-effects on people's health. Based on the experience from the stated accidents in the world, it can be expected that in Pančevo there would be a negative post-effect on the public health. Risk assessment preparation implies not only the

prevention, but also a significant analysis of the accident's post-effect. Analysis of consequences is important because negative effects of chemical substances on public health can realistically be seen. As conclusion, it can be stated that there are certain substances that at the time of the accident do not cause mortal effects (acute affect), but their effects are manifested after a certain number of years (chronic effect). The fact that such substances exist has caused the experts to include the so-called «post-effects» (proven in accidents, particularly in children) in the chemical accident risk assessments. Chromosome aberration, as a possible direct consequence, changes permanently the genetic structure and may result in a great number of anomalies, as well as in serious diseases of the human population living and working in the area.

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