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GEOGRAPHIC PERSPECTIVES ON TECHNOLOGICAL HAZARDS AND THEIR MITIGATION

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INTRODUCTION

New regulations on the conditions, organization, and methods for analysis, assessment and mapping of disaster risks were recently introduced in Bulgaria (Н а р е д б а, 2012). Some deficiencies are identified in the Ordinance, e.g., a number of hazards are not dealt with, despite the explicit claims to the opposite, which leads to the conclusion that hazard sources' research receives insufficient attention.

This investigation aims to demonstrate the potential of the geographic perspective on technological hazards to contribute to the theory and practice of hazards mitigation. To this end, the paper is divided in four sections. In the first section, the author offers a definition of technological hazard from a geographer's point of view and points out two aspects where geographic expertise plays a crucial part: a/ outlining and characterization of the scale and boundaries of hazards' impacts and b/ formulation of strategies for minimization of the damage to the geographic system. The second section provides a critical review of specific technological hazards typologies and provides suggestions for further investigation in that field. Next, the paper proposes a classification of the ten municipalities under investigation in three classes, according to their hazard source(s) characteristics and degrees of risk they present. The last task of this research is to put forward basic principles of a theoretical model of a Hazard Mitigation GIS and propose its elements, structure, and most important functions.

The paper uses data and materials from extensive field work at the local level (2012–2013) in the Northwestern Bulgaria that the author performed under the auspices of two projects on technological hazards, in which the National Institute of Geophysics, Geodesy and Geography at the Bulgarian Academy of Sciences was a partner (Z h e l e z o v, ed.) 2013; К у л о в, 2013 unpublished). Research methods include critical geographic analysis and assessment of Bulgarian, EU, U.S. Nuclear Regulatory Commission, and International Atomic Energy Agency (IAEA) regulations, regional and municipality-level administrative documentation and databases, as well as geographic typology, classification, and modeling. Nuclear power production, one of the best internationally regulated industries, in terms of safety protection and hazards mitigation, serves in this study as a methodological example in dealing with other hazard sources.

TECHNOLOGICAL HAZARDS AND THEIR MITIGATION: A GEOGRAPHIC PERSPECTIVE

A 2012 Bulgarian government ordinance (Н а р е д б а ..., 2012), which lays down the conditions, organization, and methods for disaster risks analysis and assessment claims that the analysis and assessment of such risks should include identification and definition of the characteristics of every(!) hazard (Article 4). According to K a t e s et al. (1983, p. 7027) definition of risk as a measure of hazards, however, the Ordinance lists only five types of disaster risks: seismic, flood, nuclear or radioactive, geological, and forest fire. A number of technological hazards, like:

– explosion,

– fire from technological sources,

– structural failure/damage (dams, bridges, buildings, etc.),

– fall of aircraft and other flying objects,

– transportation of dangerous (radioactive, flammable, explosive, corrosive, oxidizing, asphyxiating, biohazardous, toxic, pathogenic, or allergenic) substances (solids, liquids, or gases),

– power outage,

that certainly present risks of disasters, are missing from this particular regulation. Most likely technological hazard sources in this respect would be economic and public infrastructure objects.

Moreover, the cited ordinance necessitates “spatial indication of the territories exposed to the hazard” – a phrase that apparently refers to cartography, but can hardly testify to the use of much geographic expertise in this text. Finally, the document, issued in 2012 and amended as recently as 2014, does not even mention sources of hazard or disaster, or the term “prevention.”

Geography is one of several sciences that provide significant insights into technological hazards and serve the theory and practice of their mitigation. From a geographer’s perspective, the definition of technological hazards describes them as threats of accident phenomena and/or processes of technological origin that can potentially cause significant damage to a geographic system, its elements (most importantly, life, human society, culture, nature, and/or material assets) and their interrelations. The temporal perspective is intricately interwoven in this definition: most significant, i.e., dangerous, are the types of technological hazards that can have long-lasting adverse effects on individual or society’s mental, physical, economic, and socio-cultural well-being.

The geographic view on technological hazards involves two intricately related aspects. The first refers to the geographic scale and boundaries of the significant negative impact of the accident phenomenon or process. The second perspective relates to strategies to minimization of damage to concrete elements and the structure of the geographic system. In both cases, geographic analysis and assessment of the disaster source, including its location, forecasting of the magnitude and scale of impact, as well as prognostication of possible effects on the affected geographic system, is crucial for hazard mitigation and disaster prevention. This kind of research is also of great practical value to a wide spectrum of activities, including the economy (e.g., production site selection, the insurance and re-insurance industries), public safety, civil protection, public health, public information, environmental protection, spatial planning, and property damage and destruction prevention.

TYPOLOGY OF THE TECHNOLOGICAL HAZARDS ACCORDING TO THEIR SOURCES

The single most important activity for hazard mitigation is prevention, which is why hazards' origins should be examined with meticulous care. According to their sources, hazards are generally differentiated in two large types: natural and anthropogenic. Technological hazards make a sub-group within the anthropogenic hazards. Human misjudgment, accident, negligence and/or error serve as direct causes for malfunctions of technological origin. Human intent, however, plays an indirect role with technological hazards, only to the extent that sociological disasters (e.g., war, terrorism, crime, civil disorder) can also cause technological hazards.

S h o w a l t e r and M y e r s identify also "na-tech" events and define them as 'natural disasters that create technological emergencies' (1994, 169). In fact, natural phenomena and processes (e.g., earthquakes, floods, fire) can cause technological hazards even without reaching disastrous proportions. N i k o l o v a (1998) has proposed a typology of technological hazards in Bulgaria, which uses the characteristics: rate of occurrence, severity of damage, affected geographic scale, and approximate quantity of affected people, to add two more types to the "na-tech" events, discussed above. The first type is identified as "extreme" – most unlikely to happen but with potentially catastrophic consequences (p. 40). Nuclear power production accidents immediately stand out as an example in this hazard category, due to their exceptionally large-scale and long term effects. The second type of technological hazards is descriptively defined as more frequent, "regional or local in character, and affecting a limited number of people" (N i k o l o v a, 1998, 40).

A critical analysis of this typology shows that technological hazards are classified according to different characteristics. In the case of the "na-tech" hazards, the employed criterion concerns the origin of the phenomenon or process, while "frequency of occurrence" and "severity of damage" are the leading features in the "extreme" hazards category. In the "more frequent" category of hazards, the severity of damage is only limited to the number of people, while environmental or property damage are not taken into consideration. Finally, geographic scale appears as criterion only in one of Nikolova's types of technological hazards, while it is apparently quite relevant for them all.

Further theoretical work on the typology and, particularly, the classification of technological hazards has to necessarily include their quantitative characteristics. Risk assessment and forecasting are, in fact, not only very useful criteria for hazard typologization, but also absolutely necessary to the practice of hazard mitigation. Nevertheless, they have received inadequate attention so far.

CLASSIFICATION OF THE WEST BULGARIAN MUNICIPALITIES ALONG THE DANUBE RIVER ACCORDING TO CHARACTERISTICS OF THEIR TECHNOLOGICAL HAZARD SOURCES AND DEGREES OF RISK

To contribute to the typologization and classification of technological hazards, this paper examines hazard sources at the municipality level. Due to their importance for transnational disaster prevention and mitigation, ten administrative units along the western Bulgarian section of the Danube River, the state border with Romania, have been selected for study. The study area is slightly larger than 4 thousand km^2 with a total population of about 190 thousand people which live in 138 settlements, including 11 towns (Table 1). More detailed demographic and socio-economic analysis of the area can be found in B a l t e a n u et al. (2013).

T a b l e 1

Main Demographic and Technological Hazards and Risks Characteristics of the West Bulgarian Municipalities along the Danube River

Municipality	Area in km^2	% of Area	Population Number in thousands (2011)	% of Population	Population Density per km^2	Settlements Number	Settlements per 100 km^2
Vidin	518	13	63	33	122	34	7
Lom	319	8	28	15	88	10	3
Dimovo	409	10	6	3	16	23	6
Dolna Mitropolia	663	16	20	11	30	16	2
Nikopol	417	10	9	5	22	14	3
Mizia	201	5	8	4	38	6	3
Oryahovo	324	8	12	6	36	7	2
Kozlodui	288	7	21	11	74	5	2
Valchedrum	433	11	10	5	23	11	2
Gulyantsi	459	11	12	6	27	12	3
TOTAL	4031	100	190	100	–	138	–
AVERAGE	403	–	19	–	48	14	3.5

This paper analyzes publicly available annual data about the potential technological hazard sources and risks by municipality and technological activity provided by the Regional Inspectorates to the Ministry of Environment and Waters in Montana, Vratsa, and Pleven that control and monitor ambient air, water, and land, as well as the Regional Inspectorate for Protection and Control of Public Health to the Ministry of Public Health in Vidin (Tables 2 to 4) (Р е г и о н а л е н .., Монтана, 2012; Р е г и о н а л е н.., Враца, 2012; Р е г и о н а л е н.., Плевен, 2012; Г о д и ш е н .., 2013; А к т у а л и з и р а н ..., 2013). According to the 2012, amended in 2014, Ordinance, other government bodies, that are responsible for the analysis and assessment of disaster risk and implementing the ordinance, are the General Directorate for Fire Protection and Civil Defense to Ministry of the Interior, the Ministry of Regional Development, the Nuclear Regulatory Agency, and the Ministry of Agriculture and Foods (Н а р е д б а..., 2012). Unfortunately, their publicly available databases lack data on municipal level. Institutional capacity to produce the necessary information on a regular basis also seems lacking.

T a b l e 2

Sources of Technological Hazards in the "High Risk" Municipalities' Class by Settlement, Type of Sector and Degree of Risk

Settlement Type and Name	**Technologic Activity Type/ Number of Units**	**Hazard Source Sector**	**Degree of Risk**
City of Vidin – Thermal Power Plant	Non-hazardous Cinder Depot	Secondary Sector	High
	Coal-burning Energy Production		
City of Vidin – (Kozya Garbina Locality)	Municipal Waste Depot	Service Sector	
City of Vidin – Pneumatic Tires Plant	Tire Manufacturing	Secondary Sector	Medium
City of Vidin – Vidahim	Closed Industrial Waste Depot		
City of Vidin – Southern Industrial Zone	Municipal Construction Waste Depot	Service Sector	
City of Vidin	Pump Manufacturing	Secondary Sector	
	Foundry/2		
	Construction Materials/2		
	Paints Manufacturing		
	Vehicles Dismantling Centers/3		
	Transport/2	Service Sector	
	Dry Cleaning		
	Petrol Terminal		
	Recyclables Collection Sites/7		
Town of Dunavtsi	Recyclables Collection Site	Secondary Sector	
Village of Pokraina	Vegetable Oil Refining		
Village of Novoseltsi	Tire Regeneration		
Village of Koshava	Gypsum Quarrying and Production of Construction Materials	Primary and Secondary Sectors	

City of Vidin	Sand Quarrying in the Danube River	Primary Sector	Low
	Limestone Quarrying and Asphalt Production/3	Primary and Secondary Sector	
	Municipal Herb Processing Centers/7	Secondary Sector	
	Electronic Components/2		
	Milk Products		
	Furniture Production/3		
	Socks Production		
	Food Processing/3		
	Meat Processing/2		
	Grain Mills and Bread Production		
	Refrigerators and Air Conditioners Repairs	Service Sector	
	Gas Station/3		
	Paints Trading/3		
	Non-hazardous Industrial Solid Waste Depot		
	Municipal Waste Dumps About to be Closed		
	Coal Packaging		
	Wine Making and Trade		
	Hospital		
Village of Novoseltsi	Pig Farm	Primary Sector	
Village of Zheglitsa	Liquid Chemicals Waste Storage	Service Sector	
Village of Negovanovtsi	Agricultural Production	Primary Sector	
Village of Antimovo	Grain Mill	Secondary Sector	
Town of Dunavtsi	Meat Processing	Secondary Sector	
	Grain Mill	Secondary Sector	
Village of Koshava	Reclamation of Gypsum Quarries	Service Sector	
Village of Slanotrun	Tire Recycling	Secondary Sector	
Village of Gradets	Fishery	Primary Sector	

Town of Lom	Pesticide Storage Facility	Primary Sector	High
	Metal Pellets Production	Secondary Sector	
	Brewery	Secondary Sector	Medium
	Military Goods Production		
	Metals Processing Plant		
	Recyclables Processing/5		
	Vehicles Dismantling Center/2		
	Port Facility	Service Sector	
	Limestone Quarry/2	Primary Sector	Low
	Bread Production	Secondary Sec-tor	
	Electrical Components Produc-tion		
	Meat Processing Plant/2		
	Milk Processing Plant		
	Foundry		
	Winery		
	Clothes Production		
	Fork Lift Trucks Production and Service		
	Pipe Production		
	Convectors Production		
	Herbs Processing Facilities/3		
	Soft Drinks Production		
	Sewage System	Service Sector	
	Wholesale Paint Trading Busi-ness/3		
	Household Waste Depot		
	Waste Depot to be Closed		
	Hospital		
	Non-hazardous Waste Storage		

<table>
<tr><td>Village of Dobri Dol</td><td>Stock Breeding</td><td>Primary Sector</td><td rowspan="3"></td></tr>
<tr><td>Village of Staliiska Mahala</td><td>Construction Materials Production</td><td>Secondary Sector</td></tr>
<tr><td>Village of Kovachitsa</td><td>Liquid Waste Depot</td><td>Service Sector</td></tr>
<tr><td rowspan="6">Town of Dimovo</td><td>Pesticide Storage Depot</td><td>Primary Sector</td><td>High</td></tr>
<tr><td>Municipal Herb Processing Centers/11</td><td>Primary and Secondary Sector</td><td rowspan="2">Medium</td></tr>
<tr><td>Metals Processing</td><td>Secondary Sector</td></tr>
<tr><td>Household Waste Depot</td><td rowspan="3">Service Sector</td><td rowspan="8">Low</td></tr>
<tr><td>Gas Station</td></tr>
<tr><td>Sewage System</td></tr>
<tr><td rowspan="3">Village of Archar</td><td>Grain Mills</td><td>Secondary Sector</td></tr>
<tr><td>Sewage System</td><td rowspan="2">Service Sector</td></tr>
<tr><td>Gas Station</td></tr>
<tr><td>Village of Bela</td><td>Metals Processing</td><td>Secondary Sector</td></tr>
<tr><td>Village of Oreshets Station</td><td>Limestone Quarry</td><td>Primary Sector</td></tr>
</table>

T a b l e 3

Sources of Technological Hazards in the "Medium Risk" Municipalities' Class by Settlement, Type of Sector and Degree of Risk (The degree of risk for the Dolna Mitropolia and Nikopol Municipality is assigned by the author on the basis of identical technological activities)

<table>
<tr><th>Settlement Type and Name</th><th>Technologic Activity Type/ Number of Units</th><th>Hazard Source Sector</th><th>Degree of Risk</th></tr>
<tr><td rowspan="2">Town of Dolna Mitropolia</td><td>Vegetable Oil Production</td><td rowspan="2">Secondary Sector</td><td rowspan="3">Medium</td></tr>
<tr><td>Sugar Production</td></tr>
<tr><td rowspan="2">Village of Gorna Mitropolia</td><td>Poultry Farm</td><td>Primary Sector</td></tr>
<tr><td rowspan="3">Construction and Household Waste Depot</td><td rowspan="3">Service Sector</td><td rowspan="11">Low</td></tr>
<tr><td>Village of Komarevo</td></tr>
<tr><td>Village of Baikal</td></tr>
<tr><td rowspan="2">Town of Trastenik</td><td>Furniture Production</td><td>Secondary Sector</td></tr>
<tr><td>Gas Station/2</td><td rowspan="2">Service Sector</td></tr>
<tr><td>Village of Bozhuritsa</td><td>Sewage System</td></tr>
<tr><td>Village of Komarevo</td><td>Meat Processing</td><td>Secondary Sector</td></tr>
<tr><td rowspan="3">Village of Krushovene</td><td>Stock Breeding</td><td>Primary Sector</td></tr>
<tr><td>Gas Station</td><td rowspan="2">Service Sector</td></tr>
<tr><td>Liquid Chemicals Waste Storage</td></tr>
<tr><td>Village of Orehovitsa</td><td>Clay Quarrying</td><td>Primary Sector</td></tr>
<tr><td rowspan="4">Town of Nikopol</td><td>Paper Production</td><td>Secondary Sector</td><td rowspan="2">Medium</td></tr>
<tr><td>No Water Purification and Sewage System</td><td>Service Sector</td></tr>
<tr><td>Liquid Chemicals Waste Storage</td><td>Primary Sector</td><td rowspan="2">Low</td></tr>
<tr><td>Hospital</td><td>Service Sector</td></tr>
<tr><td rowspan="3">Village of Muselievo</td><td>Batteries and Cleaning Products Plant</td><td>Secondary Sector</td><td>Medium</td></tr>
<tr><td>Fruit Distillery</td><td>Secondary Sector</td><td rowspan="5">Low</td></tr>
<tr><td>Construction and Household Waste Depot</td><td>Service Sector</td></tr>
<tr><td>Village of Batsova Mahala</td><td>Stock Breeding</td><td>Primary Sector</td></tr>
<tr><td>Village of Novachene</td><td>Meat Processing</td><td>Secondary Sector</td></tr>
<tr><td>Village of Dragash Voivoda</td><td>Milk Processing</td><td>Secondary Sector</td></tr>
</table>

Town of Mizia	Paper Production Installation	Secondary Sector	Medium
	Poultry Breeding Installation	Primary Sector	
	Plastic Processing	Secondary Sector	Low
	Wood Processing		
	Closed Household Waste Storage	Service Sector	
Village of Sofronievo	Water Power Production Plant/2	Secondary Sector	
Town of Oryahovo	Regional Non-hazardous Waste Depot	Service Sector	Medium
	Metal Processing, Spare Parts Production/2	Secondary Sector	Low
	Recyclables Collection Site/2		
	Hospital	Service Sector	
	Ferry Port		
	Closed Household Waste Depot		
	Municipal Sewage System		
	Gas Station		
Village of Selanovtsi	Wine Making	Primary Sector	
	Crude Oil and Natural Gas Drilling and Pumping		
Village of Leskovets	Wine Making		
	Crude Oil and Natural Gas Drilling and Pumping		
Town of Kozlodui	Poultry Breeding Installation	Primary Sector	Medium
	Auto Repairs	Service Sector	Low
	Dry Cleaning		
	Gas Station/4		
	Radioactive Waste Storage		
	Closed Household Waste Storage		
Village of Butan	Construction Materials Production	Secondary Sector	

T a b l e 4

Sources of Technological Hazards in the "Low Risk" Municipalities' Class by Settlement, Type of Sector and Degree of Risk (The degree of risk for the Gulyantsi Municipality is assigned by the author on the basis of identical technological activities)

<table>
<tr><th>Settlement Type and Name</th><th>Technologic Activity Type/Number of Units</th><th>Hazard Source Sector</th><th>Degree of Risk</th></tr>
<tr><td rowspan="6">Town of Valchedrum</td><td>Herbs Processing Facilities/3</td><td rowspan="4">Secondary Sector</td><td rowspan="7">Low</td></tr>
<tr><td>Construction Materials Production</td></tr>
<tr><td>Tire Regeneration</td></tr>
<tr><td>Recyclables Processing/2</td></tr>
<tr><td>Sewage System Reconstruction</td><td rowspan="3">Service Sector</td></tr>
<tr><td>Gas Stations/2</td></tr>
<tr><td>Village of Zlatia</td><td>Liquid Waste Depot</td></tr>
<tr><td rowspan="4">Town of Gulyantsi</td><td>Stock Breeding/2</td><td>Primary Sector</td><td rowspan="6">Low</td></tr>
<tr><td>Liquid Chemicals Waste Storage</td><td rowspan="4">Service Sector</td></tr>
<tr><td>Refrigerators Repairs</td></tr>
<tr><td>Refrigeration Storage</td></tr>
<tr><td>Village of Milkovitsa</td><td>Construction and Household Waste Depot</td></tr>
<tr><td>Village of Kreta</td><td>Clay Quarrying</td><td>Primary Sector</td></tr>
</table>

On the basis of analysis and assessment of the above data and documents, as well as the author's own field work in the study area, the selected municipalities have been separated in three classes, according to the degree of risk that the potential technological hazard sources on their territory present (Table 5).

The "high risk" class of municipalities contains the municipalities of Vidin and Dimovo from the Oblast of Vidin and Lom from the Oblast of Montana. The largest in population Municipality of Vidin concentrates the highest number – a total of 73 – of the potential hazard sources in the studied area (38% of the total number). To complicate the situation even further, only 13 of the above mentioned hazard sources are located outside the city limits. The geographic distribution of the hazard sources overlaps with the most densely populated area (122 people per km2). Thus, not only the Vidin Municipality, but particularly the City of Vidin itself, is identified as the most dangerous technological hazard "hot spot" of the study area.

The Vidin municipality contains a disproportionately large share (50%) of high risk potential polluters and in the medium risk potential polluters (45%). While the

T a b l e 5

Hazard Sources and Risk Indicators by Municipality

Municipality	Hazard Sources Number	% of Hazard Sources	Number of Sources by Degree of Risk						Number of Hazard Sources per 100 km²	Number of Hazard Sources per Thousand People
			High Risk	%	Medium Risk	%	Low Risk	%		
Vidin	72	36	3	50	27	45	42	31	14	1
Lom	30	15	2	34	11	18	17	13	9	1
Dimovo	32	16	1	16	12	20	19	14	8	5
Dolna Mitropolia	15	7	0	0	3	5	12	9	2	1
Nikopol	11	5	0	0	3	5	8	6	3	1
Mizia	6	3	0	0	2	3	4	3	3	1
Oryahovo	11	5	0	0	1	2	10	7	3	1
Kozlodui	7	3	0	0	1	2	6	4	2	0
Valchedrum	11	5	0	0	0	0	11	8	3	1
Gulyantsi	7	3	0	0	0	0	7	5	2	1
TOTAL	202	100	6	100	60	100	136	100	5	1
AVERAGE	20	–	0.6	–	6	–	14	–	5	1

actual number of the high risk polluters is not large, all three of them are located in the city: the coal-burning "Vidin" Thermal Power Plant, its cinder waste depot, and the Municipal Waste Depot (Table 2).

The vast majority of the 27 medium risk potential polluters in the Vidin Municipality are also situated in the city. The other locations in this municipality which have potential polluters from the same risk category, are the town of Dunavtsi and three villages: Pokraina (vegetable oil refinery), Koshava (gypsum quarrying and production of construction materials), and Novoseltsi (a tire regeneration plant). The potential polluter sources in this category in Vidin are concentrated in the following processing sector economic activities: construction materials production, vehicles dismantling centers, foundries, paints manufacturing, pumps manufacturing, as well as a closed industrial waste depot. Some medium risk polluters belong to service sector activities: seven recyclables collection sites, petrol terminal, dry cleaning, two transport companies, and a municipal construction waste depot. Notably, the number of vehicle dismantling and metal collection sites, as well as waste depots of different kind, is relatively high.

Potential low risk hazard sources are monitored in the City of Vidin, Town of Dunavtsi and following villages: Novoseltsi, Koshava, Zheglitsa, Negovanovtsi, Antimovo, Slanotrun, and Gradets. The first four settlements feature both medium and low risk hazard sources (Table 2). The majority of the low risk technological hazard sources in Vidin Municipality are concentrated in the secondary and, to a lesser degree, the tertiary economic sector (Table 2). The greater part of the companies process agricultural, forestry, fishing, mining and quarrying products. A significant problem in the municipality is the relatively high number of waste depots. According to NSI data for 2009, Vidin has 10 landfills located on 68 acres. Several landfills have exhausted their capacity completely and the vast majority of them have control problems (А к т у а л и з и р а н..., 2013). In addition to the economic sectors, public and private transport and combustion installations are also among the most important hazard sources in the municipality. The City of Vidin reports one of the highest maximum daily average concentrations of particulate matter (PM10) in the country, comparable to the traditional problem areas in Sofia and Pernik (Актуализиран 2013). The projected heavy traffic, expected to result from the new Danube River Bridge between Vidin and Calafat, is likely to produce yet another hazard source related to ambient air and the acoustic environment pollution.

The integrated risk analysis and evaluation of the technological activities' characteristics for all risk categories places the Vidin municipality unequivocally at the top of the "high risk" class of all ten studied local administrative units along the Danube River and further proves its "hot spot" classification (Table 5). The other two municipalities in the study area that fall within the same class are Lom (Montana Oblast) and Dimovo (Vidin Oblast) (Table 2).

Lom Municipality, with its population of about 25 thousand people (P o p u l a t i o n..., 2011), is second in the study area also with its 30 monitored possible sources of technological hazards. These include two high risk potential polluters – the Metal Pellets Production Plant and a pesticide storage facility - located in the only town in the municipality. A total of eleven medium risk potential polluters (18% of the total for the study area) are among the potentially hazardous activities of medium risk: brewing, military goods production, metals processing, recyclables processing that takes place in five locations, and vehicle dismantling (Table 1 and 2). Only one potentially hazardous activity - transportation – belongs to the service sector. Similar to the case of Vidin, all of these hazard sources are situated in the administrative center of the municipality.

The share of the low risk potential polluters in this class of municipalities is also relatively high (13% of the total). They are also located predominantly in Lom, but also feature in three of the villages: Dobri Dol, Staliiska Mahala and Kovachitsa. Machine building and food industry are the main industrial activities.

Dimovo is the third and last municipality in the study area which reports a high risk potential polluter, and is, therefore, categorized as a "high risk" class municipality. The hazard source is a pesticide storage depot, located in the largely agricultural town. There are twelve medium risk potential hazard sources in this municipality altogether (20% of the total in this category), most of which municipal herb processing centers and a metals processing facility. Overall, a total of 32 potential hazard sources are monitored in this municipality of 6 000 people, 5 of which located in the surrounding villages (Table 1). The majority of the hazards – eleven – are Municipal Herb Processing Centers. Another significant problem in Dimovo, as well as in Vidin municipalities is the pollution of farmland with construction and household waste. Waste management is identified as the most important problem of environmental preservation in Vidin Oblast (А к т у а л и з и р а н ..., 2013). Due to the below average population numbers, Dimovo has an almost five times higher than average number of hazard sources per thousand people (Table 2).

Five municipalities in the study area fall into the “medium risk” class administrative units. These are: Dolna Mitropolia and Nikopol from the Pleven Oblast, and Mizia, Oryahovo, and Kozlodui from the Vratsa Oblast. They do not list any sources of potential high risk technological hazards. The share of medium risk technological hazard polluters in this municipality class is also significantly lower – 17% – compared to the municipalities in the “high risk” category (83%). The number of sources per municipality varies between 1 and 3 versus 11 to 27 in the “high risk” category municipalities (Table 5).

The three “medium risk” technological activities in the Municipality of Dolna Mitropolia are vegetable oil and sugar production, and a poultry farm. The municipality of Nikopol monitors two such activities (batteries and cleaning products manufacturing), while the lack of municipal water purification and sewage system is also considered a “medium risk” polluter. There are two medium risk potential hazard sources in the Mizia Municipality: a paper production plant and a poultry breeding installation. The municipalities of Oryahovo and Kozlodui list only one medium risk potentially hazardous activity – a regional non-hazardous waste depot and a poultry breeding installation, respectively. All “medium risk” technological activities in this municipality category are situated in the municipal centers.

The municipalities of Kozlodui and Mizia should be regarded a special cases in this classification, due to the location of the “Kozlodui” Nuclear Power Plant (NPP) on their territory. Despite the fact that this type of technological activity is one of the most regulated – internationally and nationally – the NPP certainly represents a potential hazard source and this author has done extensive field and theoretical work on the degree of risk it presents. Neither the data, nor the evaluation criteria and methods, however, are comparable with the data that this particular study uses and for those reasons, this hazard source and, respectively, the Kozlodui and Mizia municipalities at the very least, are reserved here for potential reclassification.

The low risk activities that the Regional Inspectorates monitor in the five municipalities in the “middle risk” class vary between 4 and 12. These numbers figure below the average per municipality (14) and significantly lower than the potentially hazardous technological systems in the “high risk” municipalities (17 to 42 per municipality) (Table 5). Multiple loosely controlled construction, household, and liquid waste depots and recyclables collection sites present ecological hazards across these municipalities too. Gas stations and small water power production plants are monitored as potential hazards. Small scale technological units that produce and process agricultural goods, metals, plastic, and wood contribute to the most common hazards’ list. The primary sector features with clay quarrying and crude oil and natural gas drilling (Table 3).

Only two, out of the ten studied municipalities along the Danube River, fall in the “low risk” municipalities’ class: Valchedrum (Montana Oblast) and Gulyantsi

(Pleven Oblast). No reported high and medium risk technological activities are situated on their territory. With a total of 18 potential hazard sources, they fall below the average number and generally hold 8% of the total and 12% of the “low risk” sources of technological hazards. The most common technological units and activities that are monitored as potentially hazardous belong to the service sector (gas stations, sewage system reconstruction, construction, household, and liquid waste depots, refrigeration storage and repairs). The primary sector hazardous activities include stock breeding and clay quarrying.

In summary, the three municipalities that belong to the “high risk” class – Vidin, Lom, and Dimovo – take up only 31% of the study area and are situated in its westernmost part (Fig. 1).

These municipalities stand out among the rest by the number of hazard sources per 100 km2 of their area: the average number of hazard sources for the study area per 100 km2 is 5, while their numbers vary from 8 for Dimovo to 14 for Vidin (Table 5). The three municipalities together concentrate a 100% (a total of 6) of the high risk, 85% (a total of 50) medium risk and 58% (78) of the low risk potential technological hazard sources in the study area (Table 1 and 5). In addition to that, all of the high risk and the vast majority of the medium risk potential hazards are situated in the municipal administrative centers, which raise the degree of concentration of technological hazard sources even more. Unfortunately, these municipalities also make up the largest population and economy concentration in the study area (51% of the total population) and, except for Dimovo, make the most densely populated region. These circumstances expose a comparatively larger number of people to higher risk of tech-

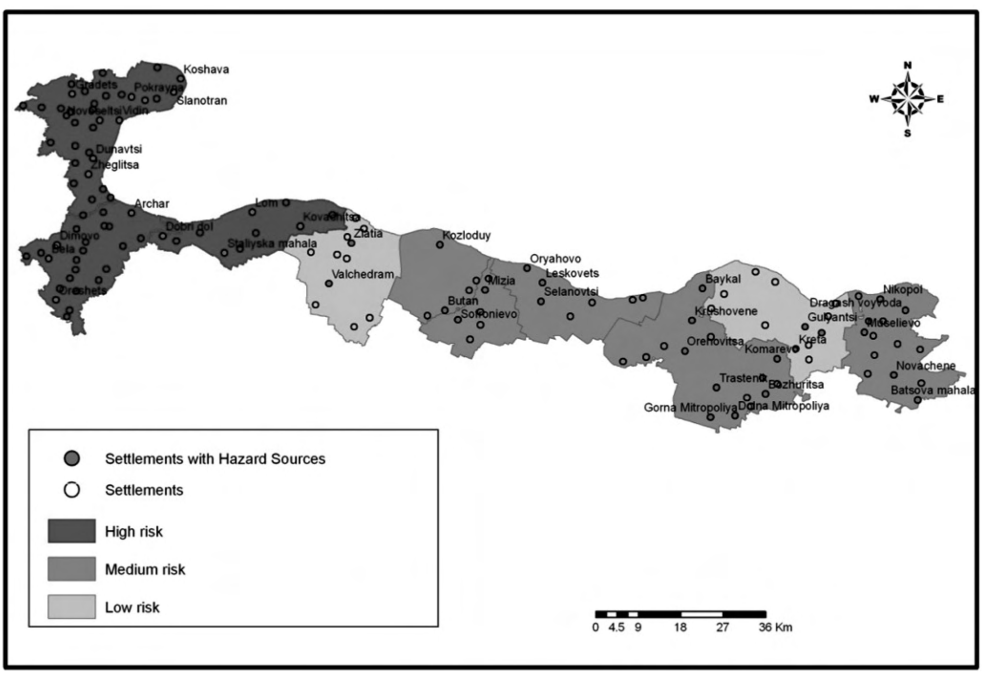

Fig. 1. Classification of the Municipalities According to Degree of Risk

nological hazards, therefore raising these municipalities' vulnerability or "potential for loss" (C u t t e r, 1996, 529). This influence, however, is not one-directional: these municipalities enjoy comparatively more favorable economic and politico-geographic, including administrative positions, which simultaneously act towards decreasing the municipalities' vulnerability.

The established concentration of hazard sources at the same time territorially limits the exposure of the geographic space of the studied area, including the majority of the settlements, to higher technological risk. As one moves eastward and downstream along the Danube, the technological hazards' degree of risk sharply diminishes. Municipalities from the "medium" and "low risk" classes take the eastern, twice larger, part of the studied region (Fig. 1).

This research is very much along the lines of Cutter's (1996) conceptual model of vulnerability: "the hazards of place" (529). The actual benefit that makes this classification of the municipalities practical is to demonstrate the importance of geographic analysis, assessment, and forecasting for hazard mitigation and disaster prevention planning. The proposed approach to the organization and presentation of the necessary geographic information for this purpose is the systems approach.

HAZARD MITIGATION GIS: A THEORETICAL MODEL

Analysis of topical research and safety regulations in the nuclear power industry (C u t t e r, 1996; I N E S, 2008; C o m b i n e d, 2007; S i t e, 2003; E x t e r n a l ..., 2002; D i s p e r s i o n ..., 2002; S t a n d a r d ..., 1978; С а н и т а р н ы е ..., 2013; З а к о н ..., 2012; Н а р е д б а ..., 2012a; 2012b; П о с т а н о в л е н и е ..., 2012; Н а р е д б а ..., 2004a; 2004b; 2004c; 2004d) leads to identification of two mutually supporting hazard mitigation strategies, in which the geographic perspective and GIS-aided analysis and assessment are instrumental. Ultimately, the main goals in both instances are selection of the safest possible site for the respective technological system and minimization of possible disaster damages. For that purpose, regulations categorize hazard sources in two types – external and internal – in respect to the technological site (Н а р е д б а ..., 2004a). The differentiating criterion is sources' location and, therefore, the directions of their influences.

The first strategy emphasizes prevention, i.e., site selection that will minimize the effects of "external" hazards of any type. The proposed list of external hazards, which should be assessed under nuclear power regulation ordinances, includes the following:

– Extreme weather conditions;
– Earthquakes;
– External flooding;
– Aircraft crashes;
– Industrial activities and transportation in the vicinity of the site;
– Sabotage and subversion;
– Electromagnetic fields (Н а р е д б а..., 2004a, Art.13).

The second strategy of hazard mitigation, in which geography plays a vital role, stresses site protection and emergency civil defense planning. In this instance, the ordinance (Н а р е д б а ..., 2004a, Art.12, 4) requires the assessment of hazards that are "internal" to the technological system's site. These include:

– Forces induced by the destruction of pipelines under high pressure, like jet forces and pipe whipping;

– Internal flooding and flooding caused by leaks or breaks in piping, pumps and valves;

– Impacts from flying objects caused by the failure of components;

– Load drop;

– Internal explosions;

– Fires.

The categorization above is neither absolute, not it is comprehensive. Nevertheless, its principles can adequately serve the purpose of conceptualization of a theoretical model of Hazard Mitigation GIS.

The results from the analysis and assessment of the regulations and NPP site selection research focused on hazard mitigation (the nuclear industry is the most heavily regulated – nationally and worldwide), as well as the study of the western municipalities along the Bulgarian sector of the Danube River, show that the conceptualization of hazard mitigation as a system leads to a theoretical model, which includes the following elements:

a) Source(s) of Hazards, including particular constructions and technologies sites, i.e., technological hazard sources (Fig.2);

b) Region(s) of Impact (Fig. 3), which vary in every occurrence and are dependent on the particular type of hazard. Objects of monitoring and investigation in this case are areas with higher temporary or permanent human population density and animal farms, and include the social infrastructure (education, health, social and other facilities, recreation, sports and social events locations, markets, bus stations), economic facilities, administrative offices. This part of the research focuses on the vulnerability of places and its geographic results take the shape of regions of various

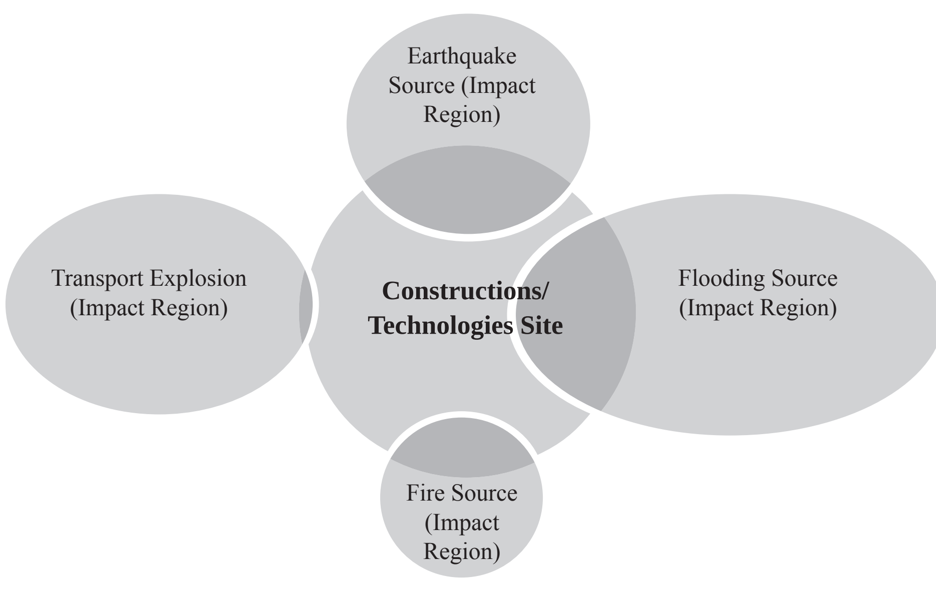

Fig. 2. External Hazard Sources and their Impact Regions

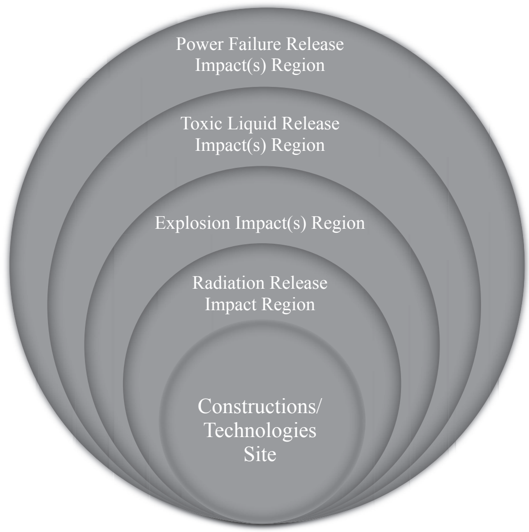

Fig. 3. Internal Hazards and their Impact Regions

vulnerability. It strongly relates to emergency planning – a 5th level organizational hazard mitigation measure (Н а р е д б а ..., 2012) – that requires extensive use of up to date, high quality geo-data.

The interrelations and interdependence among the hazards' sources and their impact(s) regions, including the dynamic characteristics of the geographic space involved, define the system's structure. The main functions of Hazard Mitigation GIS are to support the establishment of up to date protection and monitoring zones and all real time planning and control functions of a knowledge-based hazard mitigation management system. For this purpose, the geographic aspect of hazard mitigation requires regular monitoring, data updating, analysis, assessment, and forecasting of the individual elements' qualitative and quantitative characteristics, as well as adapting the structure of the modeled geo-spatial system to mirror the real world geospatial relations between hazard sources and their areas of impact(s).

CONCLUSION

All the "high risk" and the overwhelming majority of the "medium risk" technological hazards sources in the studied area are territorially highly concentrated in the administrative centers of the municipalities that are part of or geographically close to the population and economic hub of the Oblast (Vidin), the only Oblast center in the study area situated on the Danube River. This raises the exposure of a comparatively larger number of people, social economic infrastructure, and makes hazard mitigation a vital public activity. Nevertheless, hazards research and, in particular, risk assessment and forecasting, receive insufficient attention, which is partly due to the inadequate capacity of public institutions to gather the necessary data.

The geographic perspective on technological hazards, in terms of both source and impact regions' analysis, assessment, and forecasting, can significantly contribute to the theory and practice of hazard mitigation and disaster prevention. This includes the design of Hazard Mitigation GIS, which should be modeled after the elements and the structure of the actual geographic system and support all real time planning and control functions. Nuclear power production, one of the best internationally regulated industries in safety protection and hazards mitigation, can serve as a methodological example in hazard mitigation and disaster prevention.

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ТЕХНОЛОГИЧНИТЕ ОПАСНОСТИ И ТЯХНОТО СМЕКЧАВАНЕ: ГЕОГРАФСКИ ПОГЛЕД

Б. Кулов

(Р е з ю м е)

Настоящото изследване има за цел да демонстрира потенциала на географската наука за изучаване на технологичните опасности и подпомагане на дейностите по тяхното смекчаване. Използван е критичен географски анализ и оценка на документи на ЕС, Комисията за ядрено регулиране на САЩ и Международната агенция за атомна енергия (МААЕ), както и българска държавна, регионална и общинска документация и бази данни. Проведена е детайлна теренна работа на местно ниво в Северозападна България. Регулативната рамка и практиките за намаляване на риска, използвани в ядрената енергетика, служат като методическа основа.

На базата на характеристиките на източниците на технологична опасност и степените на риск, който те представляват, е направена класификация на десет общини по поречието на р. Дунав. Резултатите показват, че в изследваната зона източниците на опасности с „висок“ и преобладаващата част от тези със „среден“ риск са концентрирани в административните центрове само на една трета от изследваните общини. Тази силна териториална концентрация повишава вероятността от негативно въздействие върху сравнително по-голям брой хора, селскостопански животни, върху социалната и икономическата инфраструктура и прави смекчаването на технологичните опасности жизнено важна обществена дейност. Направените изводи се намират в противоречие с недостатъчното внимание, което научните изследвания и, в частност, географската оценка и прогнозиране на тези опасности получават в България. Отчасти това се дължи на недостатъчния капацитет на публичните институции за мониторинг, осигуряване и подходящо представяне на необходимите данни. Изследването предлага концептуален модел на ГИС, който би бил в помощ на теорията и практиката на смекчаване на опасностите и аварийното планиране.