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ORIGINAL RESEARCH

Human health in the flood risk management planning under the European Union Floods Directive: Pilot study in the Sava River Basin

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Abstract

The EU Floods Directive (2007/60/EC) has the purpose to establish a framework for the flood risks assessment and management. It requires the implementation of coordinated measures on a basin-wide level for the reduction of adverse consequences to human health and life. However, mainly direct fatalities are taken into consideration in these plans. To develop more integrated and adaptive risk management and governance it is important to include both direct and indirect consequences. To define effective measures clearer understanding of the relation between floods and impact on human health is needed. We present a first attempt to provide a roadmap for the inclusion of health issues of concern to flood risk management within the Sava River Basin as an example. An overview of the potential flood effects to health issues was made and a roadmap plan was set up to analyse and map these flood risks. We concluded that indirect health effects can contribute significantly to the overall adverse consequences to health, and although relations are complex, a preliminary assessment could be made. Mapping of adverse consequences to health issues in the planning stages should lead to systemic insights and proposed measures in the prevention, protection, and preparedness while considering the characteristics of the river basin or sub-basins. By incorporating a health-risk-analysis in the planning process, health-oriented preparation is not only aimed at improving post-flood relief efforts, but to minimise the actual impacts and decrease post flood recovery time and costs.

Keywords: *EU floods directive, flood risk management, health risk.*

Introduction

Floods have the potential to cause fatalities, displacement of people and damage to the environment, to severely compromise economic development and to undermine the economic activities. The adverse consequences of flooding for human health are diverse and have impacts long after floods have receded. A flood event can affect human health directly causing fatalities by drowning and can affect the exposed people by injuries or direct physical trauma. Subsequently the flood event can have indirect effects associated with the damage done by the water to the natural and built environment. For example, human health can be impacted by pollution of food and drinking water sources, interruption of water supply services and threatened by limited accessibility to the medical treatment. Furthermore, floods can have detrimental impacts on local governance and public administration, emergency response, health care facilities, and education.

In 2007, the Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risks (EU Floods Directive) came into force (1). The EU Floods Directive aims "to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community" (art. 1). It provides approaches for identifying areas where potential significant risks exist or might be considered likely to occur, and for managing the risks, all at the river basin scale. In the enumeration in art. 1, human health is one of the main protection targets. Also, the preamble mentions health in two points:

- (3): "It is feasible and desirable to reduce the risk of adverse consequences, especially for human health and life"
- (14): "Flood risk management plans should [..] consider where possible [..] measures to prevent and reduce damage to human health"

Preamble point 3 speaks about "human health and life". Implicitly it is stated here that direct as well as indirect consequences of floods to human health and lives should be considered. Human health concern is therefore an integral part of the EU Floods Directive and should be taken into consideration as a part of the risk receptor.

An initial milestone when implementing the EU Floods Directive was the preliminary flood risk assessment (PFRA), which the EU Members States undertook for each river basin district, or unit of management or the portion of an international river basin district. The PFRA, among other assessments, includes a description of floods which have occurred in the past and which had significant adverse impacts on human health and life, as well as where significant adverse consequences of similar future floods might be envisaged. Based on areas identified by the PFRA, flood hazard and risk maps are prepared. Flood hazard maps cover the geographical areas which could be flooded according to different scenarios, showing the flood extent, water depths or water level, and where appropriate, the flow velocity or the relevant water flow. Flood risk maps show the potential adverse consequences associated with different flood scenarios in terms, among others, of the indicative number of inhabitants potentially affected, including their health and life. Following the maps, the flood risk management plans (FRMP) address all aspects of flood risk management and focus on prevention, protection, and preparedness measures. In 2019, the FRMPs were commissioned by the European Commission (2,3). For 16 out of those 24 FRMPs that were published by

the Member States, "strong evidence"[1] was found that potential adverse consequences to human health were considered, for 7 there was "some evidence"[2], for 1 there was "no evidence"[3] found. However, from these documents it does not become very clear how and which health risks were considered by the Member States.

A detailed analysis of the direct and indirect health impacts caused by the flood events is required by the EU Floods Directive but has not been extensively accounted for in the FRMP so far. Human health should be taken into consideration as a part of one of the risk receptors to protect the population from negative aspects of flood risks where possible. To include the variety of flood risks to all potential health issues in the flood risk management planning a roadmap is needed. Here, we provide a preliminary roadmap to incorporate health risk analysis into planning process by using the Sava River Basin as pilot study. Improvements and extensions of the analysis at a later stage are possible, but most importantly it shows that the implementation is feasible and can provide positive prevention and protection effects of human health. This roadmap was used to update the FRMP for the Sava River Basin for the second planning cycle (by 22 December 2021), and will be evaluated by the European Commission in 2024.

Overview of flood risk management planning in the Sava River Basin

Four of six countries that share the Sava River Basin, namely Bosnia and Herzegovina, Croatia, Serbia and Slovenia (Parties) are currently members of the International Sava River Basin Commission (ISRBC) established in 2005 with the main purpose to implement the Framework Agreement on the Sava River Basin (FASRB) (4), see Figure 1 for a map of the Sava River Basin. The FASRB implementation goals are the establishment of an international regime of navigation on the Sava River and navigable tributaries, establishment of sustainable water management and undertaking of measures to prevent or limit hazards, and reduce and eliminate adverse consequences, including those from floods, among others. Croatia and Slovenia are EU Member States and therefore obliged to implement the EU Floods Directive. The four countries signed the Protocol on Flood Protection to the FASRB (5), entered into force in 2015, in which all Sava countries commit themselves to implement the EU Floods Directive provisions at the Sava River Basin level.

The Sava FRMP, prepared by ISRBC in close cooperation with the relevant national institutions, was officially approved by the Parties at their 8th Meeting held in Sarajevo on October 24, 2019 (6). The Sava FRMP represents a milestone in the cooperation of the Parties leading towards fulfilment of one of the main objectives of the FASRB – to prevent or limit hazards and reduce and eliminate adverse consequences from floods to all receptors defined by the EU Floods Directive. Based on national areas with potential significant flood risk, the Sava FRMP identified 21 areas of mutual interest for flood protection at the Sava River Basin level (named AMIs), as basic units for analysing the flood risks, with a total surface of 5,659 km^2, representing 5.8% of the Sava River Basin area and home to 1.4 million people. In the AMIs 38 infrastructural measures were identified with a total value of over € 250 million while at 42 non-infrastructural measures were also identified, that mostly relate to the entire AMIs or the Sava River Basin.

[1] Defined as: Clear information provided, describing an approach followed in the FRMP to address the criterion.

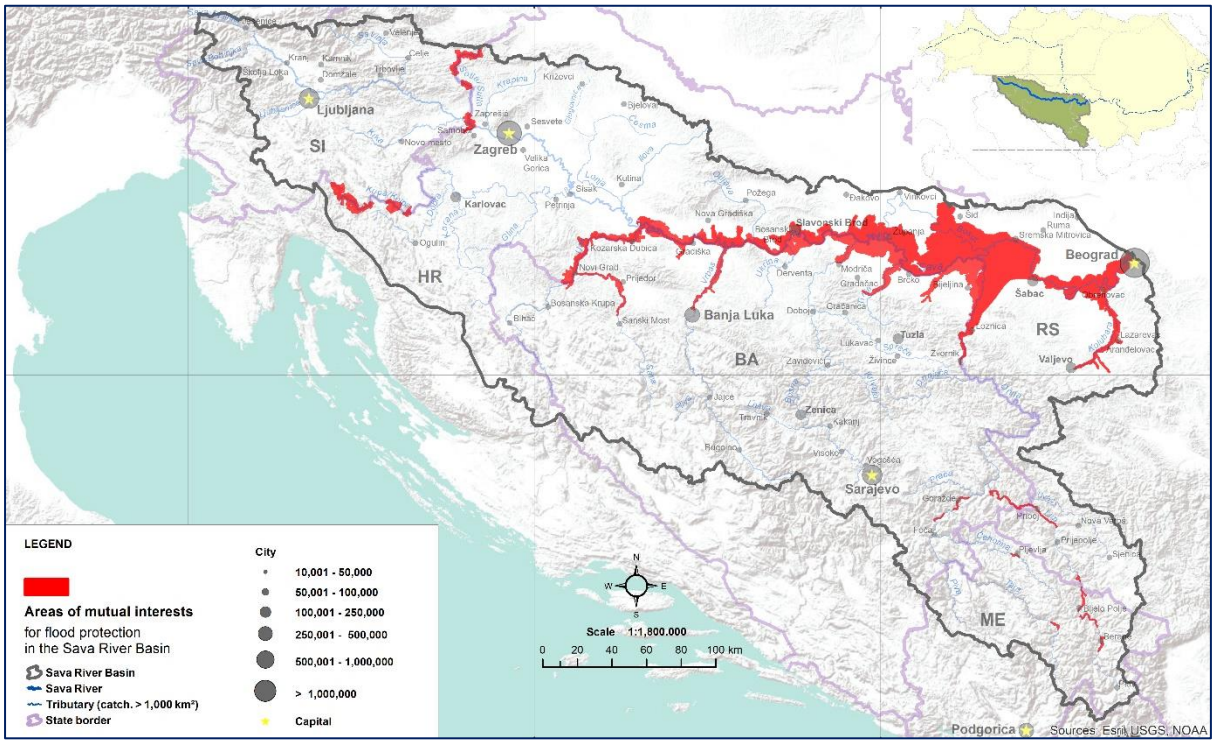
[2] Defined as: Reference to the criterion is brief and vague, without a clear indication of the approach used for the criterion. Depending on the comment in the adjacent column, "some evidence" could also be construed as "weak evidence".

[3] Defined as: No information found to indicate that the criterion was met.

The implementation of the measures will strongly contribute to meeting the commonly agreed objectives – avoidance of new flood risks, reduction of existing flood risks during and after the floods, strengthening resilience, raising awareness about flood risks, and implementing solidarity principle.

In the Sava FRMP completed as part of the first planning cycle, flood risk to human health was analysed only as an indicative number of populations in the AMIs generally endangered by floods, while indirect effects to human health were not.

Figure 1. Map of the Sava River Basin and its geographic setting (inset top right; source ISRBC). The maps also indicate areas of mutual interest (AMI) for flood protection being the planning scope of the International Sava River Basin Commission (ISRBC)



The set-up of the preliminary roadmap for the assessment of the various health risks in the Sava River Basin

ISRBC recognized the importance to incorporate an analysis with indirect health risks of flooding into the planning process and an initial stage of the update of preliminary flood risk assessment. The first step was to make an overview of the data and information available related to the consequences of the past flood events to human health. Furthermore, internationally recognized health risks of flooding are assessed in accordance with their relevance for the Sava River Basin based on (future possible) presence of pathogen and host/vector, environmental effects of climate change, and present infrastructure. Comprising the available information, the preliminary list of potential health risks that can be caused or increased by floods in the Sava River Basin was prepared. Secondly a roadmap plan was set up to analyse and map the health risks.

Overview of flood related health effects in the Sava River Basin

The (post) flood related health issues can be manifold (Table 1) and are distributed in space and time. We recognise four

overlapping time-frames: immediate health effects occur as the flood spreads (hours to few days), the short-term effects are the health risks that are present in the period that the flood is present (days after a disaster), intermediate is the immediate start of the recovery phase (days to weeks) after the onset flood event, and long-term effects is the reconstruction phase (weeks to months or years) after the onset of the flood event and may not always be recognized as caused by the flood event. The immediate health risks include fatalities from drowning and accidents, and injuries from physical trauma (7), while mental health issues, like fear and anxiety, also affect people from day one. Short-term health risks include exposure to toxic substances that might be in the water, and higher risk of outbreaks of waterborne diseases, such as Leptospirosis and diarrheal diseases (7-9). Intermediate health risks include risks of vector-borne diseases through the expansion in number and range of vector habitats (10). West Nile fever is of most concern in the Sava River Basin, since the conditions after residing of the floodwater are ideal for this mosquito (*Culex* spp.) and the mosquito is present in the region (11,12). The mosquito *Aedes albopictus* is present in the mid-section of the Sava River Basin and could raise the potential for disease transmission upon introduction of arboviruses (e.g. dengue, zika or chikungunya virus via travellers) (13). Secondary outbreaks of infectious diseases may occur due to overcrowding following population displacement (10), for example increased cases of COVID-19, which might have happened during the floods in summer 2021 in the Netherlands (14). Long-term health risks become apparent after months to years and may not always be recognized as result of the flood event, for example non-communicable diseases, mental health disorders, and the effects of chemical pollution (7,15,16). Other long-term effects include food insecurity, as harvests may be destroyed by the water or chemically contaminated, machinery is damaged, and decrease in production of farm animals due to stress or illness (7,17). Extra pressure on the health system arises due to incidents with displaced landmines and unexploded objects, since warning signs are washed away, or the object is displaced with the water or a landslide (17). In addition, on the wet walls in houses mould could grow (as well as in the flooded parts of the buildings as other locations due to rising damp). The fungi can cause respiratory infections and breathing problems (18,19).

The anticipated mortality and morbidity of injuries and diseases may subsequently be exacerbated by infrastructural losses impacting treatment availability and/or access to alternative sources. For example, broken health care services or damaged hospitals lead directly to an increase in the health burden as the health care becomes limited or lost. Damage or disruption of ICT infrastructure, transport systems threaten the delivery of supply like water, food, medicine and manpower. Damage to water supply and sanitation can (in)directly increase the burden of water-borne diseases. In the end, the health burden is expected to vary between affected populations (related to their vulnerability, exposure and capacity to reduce risks and cope with the event), type of flood (slow or fast onset) and the background health situation of the population and their access to health services.

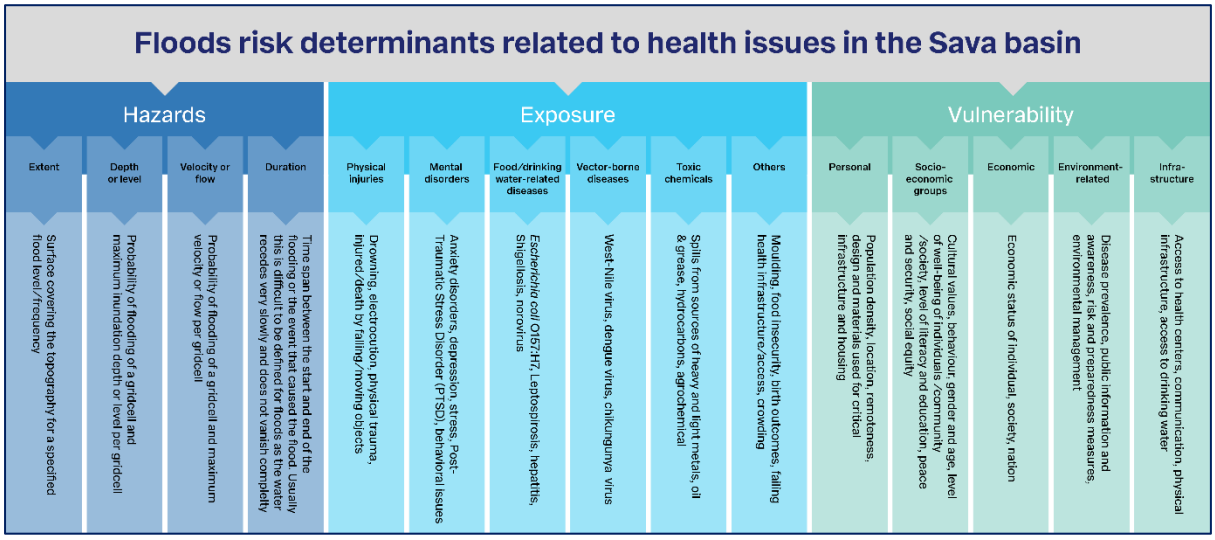
A comprehensive Flood–Health risk analysis for the Sava basin

For detailed elaboration of the health issues, health risks should be mapped and analysed to be able to include them in the flood risk management planning stages. For the mapping and analysis of health risks, we recognised three main dimensions, i.e., “Hazards”, “Exposure” and “Vulnerability” (Figure 2). The “Hazards” dimension describes the components related to the floodwater itself. The “Exposure” dimension contains the various health risk

categories that vary in the underlying mechanisms. The "Vulnerability" dimension indicates parts of the population that are susceptible, and the healthcare infrastructure that, when affected, exacerbates local vulnerability during and after floods. All dimensions will probably have spatial 'hotspots' popping up in the mapping & analysis. Ultimately, measures to prevent or limit health risks can be aimed at lowering risks inside these dimensions, lower vulnerability (increase resilience) and lower the (exposure to) hazards.

The dimensions contain components that are quantifiable and mappable to estimate the potential health risks (Figure 2), such as chemical factories as potential sources of chemical pollution, farms, sewers, septic tanks, wastewater treatment plants as sources of microbial pollution. Some components are easier to quantify than others. Long-term health effects, for example mental health effects and birth outcomes, are difficult to relate to a flood event and to quantify. The vulnerable population can be estimated and mapped based on for example age distribution, socio-economic spatial data, remoteness/isolation, transport capabilities, etc. The actual mapping is proposed to be further elaborated in the next planning stages. If desired, an aggregated health risk can be produced to identify areas of risk to hazards and exposure, and/or higher vulnerability.

Figure 2. Overview of determinants of health risk during and after floods, result of quick scan. The figure was inspired by the INFORM Risk Index (20) made for disaster related epidemics



The health risk mapping and analysis in the next planning stages should lead to systemic insights and proposed measures in every phase of the flood risk management planning cycle. The analysis feeds into prevention and preparedness phases to target known causes of hazards and exposure, to limit these in case a flood happens. Also, the (spatially) identified vulnerable population groups can be better prepared, and supporting health infrastructure, linked to its serving area and its supporting infrastructure, be made more resilient to floods. Responses in high-risk areas, now with known health effect causes, can be more informed about resources needed, and similarly the recovery efforts can be more targeted if the spatial distribution of potential health risks is known.

By incorporating a health risk analysis into flood risk management planning, health-oriented preparation is not only aimed at improving emergency relief efforts during a flood, but also to lower the actual impacts and efforts needed by more integrated flood management planning.

Conclusion for Sava River basin

From the quick scan of existing evidence for the pilot study in the Sava River Basin it became clear that the indirect health risks can contribute significantly to the overall health risks of floods. The potential health risks are dependent on many components, like disease presence in the region, infrastructure, and socio-economic conditions, cultural values, and behavior. Nonetheless, a preliminary assessment could be made. The next step would be the health hazard, exposure & vulnerability mapping and analysis.

Future

The previous paragraph shows that a preliminary assessment of direct and indirect health risks is feasible and leads to new insights for flood risk management. Although a fully quantitative analysis is a challenge, a quick scan seems sufficient to put the indirect health risks on the agenda and is recommended for all (European) river basins. The preliminary health risk scan can be progressed to a mature qualitative assessment to ultimately derive health risk reducing actions and measures in the next cycle of the flood risk management planning.

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Table 1. ***Potential health impacts in the Sava river basin. Abbreviations used: PTSD, post-traumatic stress disorder; WWTP, wastewater treatment plant***

Health impact pathway	Specific health impact	Transmission route	Health impact source	Response phase	Potential (GIS)indicator	Ref.
Accidental death and injuries	Drowning, electrocution, physical trauma, wounded/death by falling/moving objects	Besides accidents, death and injuries could come from failing infrastructure, displaced landmines and unexploded objects	Water depth, infrastructure, collapsing danger of buildings, early warning of citizens	Immediately	Water depth, city plan, infrastructure, population density	7, 10, 17
Mental health and well-being	Anxiety, depression, stress, PTSD, behavioral issues	-	Warning of citizens, personal losses, impact of flood on live, first aid response time	Important during each phase	-	3, 16, 17, 22
Water related infections	*Escherichia coli O157:H7*	Bacteria that spreads via the fecal-oral route, contaminated food and water	Bacterial reservoir in cattle and other ruminants. Contaminated water due to overflowing septic tanks, WWTP, sewage, or agricultural runoff.	First weeks	Location of drinking water reservoirs, septic tanks, WWTPs, sewage system, agricultural land, city plan, population density	7, 8, 10, 13
	Leptospirosis	Bacteria that spreads via urine of infected animals into water/soil/food	Agricultural and stormwater runoff			
	Hepatisis A	Virus spreads via fecal-oral route, mainly contamination of water/food	Overflow septic tank/WWTP/sewage, agricultural runoff, stormwater runoff, infected person			
	Cryptosporidiosis	Parasitic disease spreads via fecal-oral route, mainly contaminated water sources	Overflow septic tank/WWTP/sewage, infected person			
	Giardiasis	Parasitic disease spreads via fecal-oral route from humans or infected animals	Overflow septic tank/WWTP/sewage, agricultural runoff, stormwater runoff, infected person			
	Shigellosis	Bacteria spread via fecal-oral route, or contamination of water and food.	Overflow septic tank/WWTP/sewage, infected person			
	Norovirus	Virus spreads via fecal-oral route, vomit, contamination of water/food	Overflow septic tank/WWTP/sewage, infected person			

Health impact pathway	Specific health impact	Transmission route	Health impact source	Response phase	Potential (GIS)indicator	Ref.
	Rotavirus	Virus spreads through fecal-oral route, or contamination of water and food	Overflow septic tank/WWTP/sewage, infected person			
Vector borne diseases	West-Nile Virus	Bite by *Culex* spp	Endemic in the region	First weeks to months	Flooded area, population temperature, rain	7, 12, 21
	dengue, chikungunya	Bite by *Aedes* spp	Via viraemic visitors, but can become endemic in the future			
Vaccine preventable diseases	Tuberculosis	Spreads through the air	Infected person, overcrowding	Months	Location and population density of temporary shelters	13, 17
	Poliomyelites	Polio virus spreads via person-to-person contact	Infected person. It is a human only disease and is mainly associated with poor hygiene and overcrowding.			
Chemical pollution e.g. heavy and light metals, oil and grease, hydrocarbons, agrochemicals	Skin diseases, earache, nausea, cancer, liver and kidney diseases, gastrointestinal diseases, cardiovascular diseases, neurological diseases, carbon monoxide poisoning	-	Chemicals can come into the water in many ways e.g. broken equipment in hospitals (x-ray, thermometers, heating systems), runoff of chemical dump, chemical plant	Months to a year	Location of factories, hospitals, water depth, flooded area, water inlet point for drinking water	3, 11
Secondary effects				Months to a year		7, 10, 11, 17
Moulding	Asthma, allergy symptoms, respiratory disorders	-	Damp surfaces, poor living standards			
Food insecurity	Undernutrition, micronutrient-related malnutrition, diseases from carcasses of (farm)animals, health issues of farm animals	-	Polluted agricultural lands, broken/loss agricultural material, sick animal husbandry			

Health impact pathway	Specific health impact	Transmission route	Health impact source	Response phase	Potential (GIS)indicator	Ref.
Birth outcomes	Unappropriate birth conditions (causing problems for mother and/or child), low birth weight, spontaneous abortion	-	Stress, well-being, food insecurity			
Failing health infrastructure/ lower accessibility	Disruption/lowering of health services resilience	-	Inaccessible health care facilities, disruption of roads, broken health care material, lower accessibility of medicines			
Crowding	Infectious diseases	-	Infected person/water/food, bad hygiene			