Literature review

4.7. Natural disaster and industrial contamination - Chemicals and floods

Marita Luotamo and Kai Savolainen
FIOH, Finnish Institute of Occupational Health-
Centre of Expertise for Work Environment Development
New Technologies and Risks Team
Topeliuksenkatu 41Aa, FIN-00250 Helsinki, FINLAND
Tel +358-30-474 2860 (direct), Tel: +358-30-4741 (switch board)
Fax: +358-30-474 2110, email Marita.Luotamo@ttl.fi
internet www.ttl.fi

Globally there are over 100 000 chemicals in different uses in different industrial sectors including large scale industries and small and medium size enterprises, agriculture including professional and home scale activities, and gardening. The uses of chemicals also include cleaning and disinfection, at public institutions and at homes, and other uses such as the production and distribution of pharmaceutical products. Practically, nearly all consumer products have either been made out of chemicals or are chemicals such as plastics, paints and lacquers which are mixtures of chemicals. Several hygienic and cosmetic products are also chemical mixtures. Thus, chemicals are present everywhere in societies and communities; although there are huge differences in the used volumes of different types of chemicals used and in the diversity of different chemicals in terms of their toxicities.

There are many different ways of using, storing, transporting and discharging of chemicals and chemical-containing products, which is crucial in areas where flooding is possible. Chemicals have not so far been in any specific focus when the impacts of floods have been evaluated. The aim of this review is to analyze, based on the information available in the literature, the sources and roles of chemicals in floods in different parts of the world.

Past experiences of floods and chemicals

Chemicals may be released into the floodwater from industrial, agricultural and domestic stores. Chemicals may also contaminate the floodwater during their whole life-cycle from production to use, recycling and discharging as well as during transportation.

Floods may have multiple environmental consequences which may affect the public health directly or indirectly. These effects potentially include direct contamination of homes and other buildings, contamination of drinking water sources either by infectious or chemical materials and disruption of sewage systems, both residential and industrial. Chemicals may be released from storages, e.g. underground fuel tanks, or by remobilization of chemicals already present in the environment such as metals and pesticides. Flooding can potentially increase the amount of chemicals which run off from farms, lawns, and streets into rivers, lakes and coastal waters [1].

One source of chemical leaks in floods is the alluvial aquifers used in vertical and horizontal collector wells as important components of drinking water production. Ray et al [2] studied the river bank filtration (RBF) when permeable river bed and underlying aquifer solids are used to diminish dissolved and suspended contaminants through physical filtering, sorption and degradation. Dilution of the contaminants is also possible if the concentrations are lower in the ground water that the surface water. RBF have been widely used in Europe and United States for public and industrial water supplies.

USA - New Orleans - Hurricane Katrina

Although Katrina is classified as Hurricane, enormous flooding was one of the long lasting effects of this one of the most devastating hurricanes of recent years. United States Environmental Protection Agency US EPA) and Centres for Disease Control (CDC) have studied the possible effects of floods including the chemicals. The key-questions raised regarding human health effects of flooding associated with Hurricane Katrina were closely linked with the fundamental environmental issues addressed in the initial evaluation report by US EPA and CDC [3]. The team identified the key issues and supporting infrastructure to be included in the initial assessment: drinking water, wastewater, leaks of solid waste/debris, evoked contamination of sediments and soil with toxic chemicals. Important issues were also production of energy, dealing with natural gas pipelines and unwatering of houses from flood water. Occupational and public safety and health and security, rodent/animal control, maintaining functional roads, and assuring the integrity of underground storage tanks containing e.g. gasoline and food safety were included in the list. Occupational safety and health as well as public security was identified as cross-cutting all the other areas [3].

After Katrina hurricane, 60-80% of New Orleans city on the east side of Mississippi River was under water, and in some locations flood waters were over thirty feet deep [3] and [4]. The flood water was pumped to Lake Ponthcartrain and Mississippi rivers. In the heat and stagnation, the waters became heavily polluted with petroleum products such as gasoline from underground tanks, industrial chemicals, raw sewage, and dead animals [4]. Pardue et al [5]) found elevated concentrations of Pb, As and Cr many of which some cases exceeded the levels of drinking water standards. The results indicated that Katrina floodwater is similar to normal storm water runoff but with somewhat elevated Pb and volatile organic chemical (VOC) concentrations. The absence of major toxic contaminants was explained by several factors. These included dilution and pH of water. Because of the alkaline pH of the flood water the lead in car lease-acid batteries was not leached into the environment in any larger quantities. Alkalinity also attenuated evaporation of lead compounds in addition to chelating the lead-containing compounds that together diminished reduced leakage of lead into the environment. Pardue et al [5] though collected samples in areas in New Orleans where no chemical factories were situated. The authors concluded that more studies are needed concerning environmental exposure before one can draw any definite conclusions.

Huge quantities of the floating debris were estimated to be removed and managed and some of these materials were regarded hazardous. For example, small colloidal particulates that are suspended in the water included organic contaminants, metals and disease-causing micro-organisms. Contamination of the soil and sediments was possible because the releases from chemical plants, manufacturing facilities, refineries, homes and other buildings [3] and [4]. Over one hundred priority pollutants, such as VOCs, semi-volatile organic compounds (SVOCs), total metals, pesticides, herbicides, and PCBs were analysed. Lead was the pollutant most often found in the samples and the pollutant that most frequently exceeded the US EPA standard. The locations in which high lead concentrations were found, were know historically high in lead content.

One class of the analysed hazardous organic compounds was divided into the following categories: 1) polyaromatic hydrocarbons (PAHs) found in petroleum and coal tar products; 2) polychlorinated biphenyls (PCB); 3) pesticides; and 4) miscellaneous chemicals. Study concluded that the floodwaters redistributed some chemical toxicants, but the contaminant burden in soils and sediments generated fewer that previously assessed concerns for acute exposure and risk of chemicals. One of the local risks was the impact of a crude-oil tank failure. One of the most serious continuing risks has been the presence of high concentrations of molds, bacteria, and airborne mold spores in moisture-damaged structures causing allergies and asthma among many of the exposed [4].

Schwab et al [6] published a study conducted in New Orleans on the indicators of bacterial contamination, contamination by airborne molds or surface molds and their spores, and sediment and soil samples for lead (Pb) and arsenic (As) in flood water samples. The samples were collected in three regions of the flooded area between September 15 and October 12-14, 2005. Results showed high bacterial contamination of the surface waters as assessed by bacterial indicators of the large volumes of human waste with an origin is the sewer system of a large metropolitan region. Elevated Pb and As concentrations in soils are indicators of anthropogenic activities and are often due to cumulative deposition that may cause a risk for communities from hazardous environmental exposures. Airborne and surface molds also created a higher risk to citizen's risks of who was also verified in the study.

Ambient concentrations with passive sampling of VOC were measured in the Greater New Orleans in the aftermath of Hurricane Katrina. About 30 different organic compounds were determined including benzene, toluene, ethyl benzene, carbon tetrachloride, styrene, naphthalene, trichloroethylene, tetrachloroethylene, and chloroform, and the overall results suggested rather low concentrations of various contaminants [7].

Hurricane Katrina caused a landslide on the Louisiana peninsula, Adams et al [8] conducted a study to determine the concentrations of leachable inorganic and organic constituents in sediments and associated soils (altogether 46 samples) in New Orleans after the floodwaters had been removed. Out of the analyzed inorganic components As and Pb concentrations exceeded drinking water standards, while the other metals Cd, Cr, Cu, Hg and V showed much lower leachable levels. Benzene, most likely representing gasoline constituents, was detected over the limit of detection and the 18 analysed pesticides were below the limit of detection [8]. The authors concluded that there is a need for another study to explore the presence of heavy metals bound to soil and that are not readily leachable.

Van Metre et al [9] studied the effects of Hurricanes Katrina and Rita by analysing the samples of street mud and suspended and bottom sediments. In the bottom sediments elevated concentrations of Pb, Zn, polycyclic aromatic hydrocarbons (PAHs) and chlordane. The levels of those chemicals exceeded their median concentrations in U.S. urban lakes and guidelines for lake sediments. The authors concluded that the effects of Hurricanes Katrina and Rita on the sediment chemistry of Lake Potchartrain are limited spatially and are most likely transient.

USA - Minnesota River

Elevated methyl mercury concentrations and loadings during flooding in the Minnesota Rivers were determined after the major flooding episodes in the summer of 2002, when frequent intense precipitation events resulted in extraordinarily wet conditions in East-Central and North-Western Minnesota [10]. The authors concluded that when flooding and wet conditions in this region increase in parallel, the production of MeHg and its leaching from terrestrial areas to surface waters will also increase.

Honduras - flood following the Hurricane Mitch

In October 1998 the Atlantic tropical storm Mitch upgraded to hurricane being one of the strongest having ever hitting Central America. When the hurricane was in Honduras, it caused catastrophic floods and mud slides throughout the country [11]. The flooding increased the potential for environmental contamination by toxic chemicals from toxic waste sites, and chemicals stored at ground level. Especially, pesticides and other agricultural chemicals can be flushed into residential areas and rivers causing environmental contamination. Balluz et al [11]) evaluated the chemical contamination of potable water and the extent of human exposure to chemicals as a result of the flooding. In this study, water samples were analysed and biological monitoring analyses of serum specimens were carried out for DDT and organophosphate metabolites. There was significant contamination of soil, but no water contamination. The soil levels of chlopyrifos and parathion were 30- and 1000-times higher, respectively, than Environmental Data Quality Level. Elevated levels of chlorinated and organophosphate pesticides in adolescents were most striking. Elevated levels were found even three weeks after the hurricane, which in case of these substances with short half lives an ongoing threat of exposure have been possible for longer time. In the biomonitoring results elevated levels were found in serum p,p´-DDE (metabilite of DDT), dieldrin, organophophate metabolites, diethyl phosphate, para-nitrophenoland 3,5,6-trichloro-2-pyridinol. The authors concluded, that the elevated concentrations of organophosphates were surprising because these substances were banned in Honduras already 15 years ago, which actually shows that those substances were still used in Honduras. In the survey, the most common self-reported symptoms were headache (44.4%), tiredness and weakness (42.2%), skin rash (40%), abdominal pain (33.3%), fever (27.7%), decreased appetite (24.4%), chills (22.2%) and nausea (22.2%) - more frequent in adolescents than in adults [11].

Canada - Mackenzie Delta

Canada's longest river, the Mackenzie River, empties into the Beaufort Sea in a region known as the Mackenzie Delta. The Mackenzie Delta is the largest delta in Canada and the twelfth largest delta in the world. Its watershed drains five provinces or approximately twenty percent of Canada. Two hundred and ten kilometres in length with an average width of sixty-two kilometres, the Mackenzie Delta covers an area of 13,500 km^2 and contains approximately 25,000 lakes (http://www.bmmda.nt.ca/mackenzie_delta.htm). Headley et al [12] published the results of PAH concentrations in lake sediments and concluded that for some lakes, the concentration of PAHs decreased with decreasing flooding frequency and decreasing sedimentation rates. PAHs appear to be more consistent with biogenic and pyrogenic origin, and the overall PAH budget petrogenic source appears to be dominant.

Europe - flooding in the UK

Health Protection Agency (HPA) in the United Kingdom has reported significant flooding in England in 2007 in Yorkshire and Humber, East Midlands, West Midlands, South West, South East Central and London [13]. The outcome of this evaluation was that the dilution of the chemicals rendered the concentrations of the chemical in the flood water low, and the same applied to the possible infections from sewage in floodwater. This dilution process rendered the risks to the general public of this flooding relatively low. The Agency was of the opinion that the general public can markedly decrease the risks of infections by avoiding possible infectious floodwaters. The Agency also concluded that the same assessment is also most likely applicable to the chemical pollution even though the final conclusions still require further considerations.

Europe - flooding in central Europe - Germany, Poland and Czech

The river Elbe is one of the major rivers in Central Europe. It flows over a distance of 1091 km through Czech Republic and Germany. Extreme and widespread precipitation over Austria, Czech Republic, Slovakia and Germany lead to a disastrous flood in 2002. In the flood area there were several chemical factories, among them the Spolana chemicals factory in Czech Republic which handles and treats with particularly problematic chemical substances. Spolana is a chemical factory producing basic chemicals, pharmaceuticals and plastics. High water caused floating of chlorine tanks and loss of their containment. Altogether 80 tons of chlorine was released and most of it was diluted in the flood waters and small amounts in the air.

There were several sewage treatment works in the area. Substances from these sources gave rise to a serious pollution situation the extent of which was considered, however, to be very difficult to assess. Vegetation was damaged by gaseous chlorine, and soil and sediment were contaminated by dioxine and related compounds [14], [15] and P. Danihelka, (http://www.srv.se/upload/F%C3%B6rebyggande/NCO/Arrangemang/Workshop/Presentations/IV-Dobes.pdf). In the Czech Republic there were altogether 139 Seveso classified operators, 70 as 'A' lower tier, and 69 as 'B' upper tier operators during the September 2002 floods.

The study by Stachel et al [15] collected sediment layers from 37 sampling sites along the Elbe and the mouths of tributaries. The aim of the study was to analyze dioxins (PCDD/F), xenoestrogens-like branched nonylphenols (NP), nonylphenol ethoxylates (NPEO) and bisphenol A (BPA), organotin compounds, brominated flame retardants, trisalkylphosphates, DEHP, organochlorine compounds, PAHs, synthetic musk fragrances, radionuclides and metals. Significant concentrations of PCDD/F could be shown in several in the soil of flooded areas [15] and [14]. The concentration of NP dominated, and the origin of these compounds was most likely the discharge of treated waste water from the sewage plant. In agreement with this observation, the NP concentrations were two orders of magnitude lower upstream from the location of the leaks. The concentrations of NPEO and those of BPA were higher in the vicinity of Spolana chemicals, a manufacturer of BPA. Monobutyltin (MBT), dibutyltin (DBT), and tetrabutyltin (TeBT) were elevated in several areas, the TeBT concentration being the most remarkable. The origins for these compounds could be traced to discharges from a manufacturer of antifouling agents and the local shipyards.

In another report concerning the Elbe flood in 2002, the concentrations of various nutrients such as phosphates and nitrates, silicates and most heavy metals were within normal range. Mercury concentrations were elevated in some sampling sites, but were still below the values observed during mid-1990s. For alpha-HCH and beta-HCH up to 10-fold elevated concentrations were observed. Some herbicides like atrazin showed about 5-fold elevated concentrations (Common Wadden Sea Secretariat, Wilhelmshaven, Elbe Flood Status Reports, 2002, http://cwss.www.de/news/news/elbe-flood-2002.html#5) as compared with the normally occurring ones.

The Federal Ministry of Education and Research (BMBF, Germany, http://www.bmbf.de/en/index.php) carried out an Ad-hoc Project concerning the Elbe flood in 2002, and the outcome of the project was reported in 2003 (http://www.halle.ufz.de/hochwasser/index.php?de=1298). In this project, several chemical compounds were determined including elements Cd, Pb, Zn, Cr, Cu,, Ni, As, U, Hg, Ti, Sn, and radioactivity, organic compounds PAK, PCB, chlorobenzole, DDT, HCH, mineral oils, and regional specific compounds, dioxine. The determinations were carried out in several different places in the flooded area.

As a part of this Ad-hoc Project [16] explored concentrations of Pb, Ni, Cd, Hg, Cr, Zn, Cu, and As in the sediments of several places in the flooded area, and a wide variety of the chosen heavy metal and As concentrations were found. In the samples, As and Hg were occasionally present in higher concentrations. Cd, Pb and Ni concentrations were not elevated. As to the measured organic compounds (BaP, β-HCH, PCB, DDT, HCB, Dioxine and MKW), there were increased levels in some of the sediment samples. The concentrations were at similar level with frequently occurring levels in those specimen sites for PCB and DDT, 2 fold elevated for β-HCH and the same level or even less than usually for the other measured organic compounds [16].

Einsporn et al [17] explored possible effects of Elbe flood in 2002 to the cellular changes in flounder livers and digestive glands of blue mussels in the Elbe estuary and the Wadden Sea. The relevant concentrations of the contaminants such as organochlorides and PCBs were analysed in parallel with cellular biomarkers; elevated concentrations of insectiside metabolites were detected. Cell recovery and clear reduction in contaminant concentrations were observed in fish livers five months after the flood at nearly all sampling sites as compared with the concentrations during the episode [17].

In Czech Republic the changes of Pb and Cd were studied in the bottom sediments before and after flooding (River Malše, August 2002). The flooded area is also the main source of drinking water in this area. The mobility factors for Pb and Cd were calculated, and the results showed that the flood led to a leaching of the heavy metals present in bottom sediments into the environment [18].

In Italy, in the Dese River (Venice Lagoon) a flood was generated by a typical summer storm. For the investigation, water samples were collected for the analysis of total and dissolved metals (As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn), nutrients and the suspended particle matter (SPM) concentration. The transport of the most metals were driven by the SPM, as the increase in concentration of SPM had a high correlation with increased levels of Fe, Cu, Pb, Cr, Ni and particularly Zn transported by the stream [19].

Europe - Flooding in Spain

Mobilization of pesticides into surface waters along the Guadiamar river (Spain, 1998) on an agricultural landscape flooded by a torrential storm was studied by Donald et al [20]. The authors concluded that significant amounts of herbicides were mobilized to aquatic environments when prairie agricultural landscapes were subjected to torrential storms and flooded. Flooded wells and small municipal reservoirs used as sources of drinking water were compromised by 10 or more pesticides and some of them in relatively high concentrations. Carbera et al [21] analysed heavy metal concentrations in soil samples of seven selected areas along Guadiamar river valley affected by toxic flood, after removal of a deposited sludge. Elevated concentrations of nine elements (As, Au, Bi, Cd, Cu, Pb, Sb, Tl and Zn) out of the 23 elements analysed were higher in sludge covered soils than in unaffected soils. The values of total As, Au, Pb, Sb, Tl and Zn in sludge-affected soils were higher than the upper limits for normal soils world wide [21].

Europe - Flooding in France

Fresh floodplain deposit (FD) from 11 key stations, covering the Seine mainstream and its major tributaries were sampled from 1994 to 2000 in order to analyse the temporal trends of the metal concentrations (Cd, Cu, Hg, Pb and Zn) subsequently to flooding. Throughout the Seine River basin FD levels were elevated as were those of Cd, Cu, Hg, Pb and Zn by a factor of two or more [22].

Chemical incidence response - the role of odour

Odour can be generated from many different sources like accidental chemical spills, as well as from incinerators, landfills and mineral refining facilities. During chemical incidents, odours are often reported as 'complaints' [23] and [24]), but many times the source of odour is unkown. Odours are often perceived as either a nuisance or as a direct threat to health. The difficulty in explaining the symptoms attributed to odour is a challenge to the health protection response and regulation measures.
Smethurst [23] has developed a checklist in order to assist with the investigation of odours hazard identification, exposure assessment and risk characterisation. Also the recommendations for the acute phase response and legislative aspects as well as the recommendations for post incident investigation to manage the risk of odours. The draft checklist presented in Annex 1 [23] giving the odour characteristics and the detection threshold levels over 100 chemicals is designed as an aidememoire for public health professionals and other emergency responders when dealing with odours.

Public health impacts of chemicals in floods

Euripidou and Murray [1] reviewed three floods related to chemical incidents in England i.e. Yorkshire flood (2000), Gloucestershire fire and floods (2000) and Kent floods (October 2001). These floods were chosen, because the chemical contamination had the potential to affect public health either primary from soil or water and secondary from homes or via other contamination. This was verified by demonstrating that one or more chemicals were found in land, homes, flooding sediment or water in concentrations above or soil guideline levels with a potential to cause both acute and chronic adverse health effects.

From October 28 through November 8, 2000 in Yorkshire, severe flooding due to high rainfall caused the risk to clean-up workers to be exposed to dioxins (2,3,7,8-TCDD), because this area was earlier heavily contaminated with elevated levels of dioxins by heavy industry. There was evidence that dioxin residues may become mobilized from rivers, canals, storm water and sewage drains. In Gloucestershire, a fire destroyed approximately 160 tonnes of hazardous waste containing drams including a wide range of chemicals such as cyanide, resins and adhesives, pesticides, solvents, asbestos and low level radiation waste. In Kent floods in October 2001 vast amounts of oil waste was mobilized by the flood waters, and 140 people were evacuated to rest centres and over thousand people displaced [1].

Euripidou and Murray [1] listed the following chemicals as causes of possible chemical contamination during flooding in the case that they reported in UK.

Flooding	Source	Chemical contaminants
Storm water floods	run-off from roads, motorways and bridges	- heavy metals - pesticides, fertilizers and herbicides - hydrocarbons - oils and grease - petrol and fuel depots - spilled petroleum products - paint and rust - sodium and chlorine
Overloaded sewers	sewer pipes - residential, industrial or storm water - run off - remobilization	- variety of residential, industrial and storm waste water - domestic and industrial sources
Hazardous landfill sites	physical contamination	- hydrogen sulphide and mercaptan - persistent chemicals - asbestos - mercury
Wastewater lagoon	contamination of soil, sediment or groundwater	- VOCs - PAHs - dioxins - persistent chemicals, e.g. wood preservatives
Acid mine drainage	coal mines	- sulphides - oxidation to sulphuric acid

		- aluminium, arsenic, cadmium, cobalt, copper, iron, lead, manganese, nickel, silver and zinc

Flood related infectious diseases

Many infectious pathogens are susceptible to changes in environmental conditions, such as those caused by floods. Flooding can increase the risk of soft tissue, respiratory, diarrhoeal and vector-borne infectious diseases as a result of the direct inoculation of pathogenic organisms (tetanus, wound infections, aspiration pneumonia), the destruction of shelters and resultant crowding of surviving displaced individuals (influenza, measles, meningitis, tuberculosis), the elimination of potable water supplies (shigella, cholera), and altered vector breeding grounds or zoonotic reservoirs (malaria, dengue, abroviral encephalitis. Flooding can also have long term and secondary effects, such as disruption of vaccine, maternal - child health, and tuberculosis public health programmes [25] and [26].

Guidance for floods

All the chemicals despite the use should be stored in a proper way following the regulatory and other guidance given by the national authorities. International bodies, like United Nations different organisations ILO (International Labour Organisation), WHO (World Health organisation) and CIEN (The Chemical Information Exchange Network) as well as OECD and European Union legislation, recommendations and guidance provide huge amount of information for the safe management of chemicals.

Several institutes and authorities in Europe and USA have published guidance how to prepare for floods, what to do during and after floods.

- Health and Protection Agency, Flooding, United Kingdom
  - http://www.hpa.org.uk/flooding/default.htm
- NIEHS web pages
  - (http://tools.niehs.nih.gov/wetp/index.cfm?id=391)
- CDC - Floods and returning home
  - http://www.bt.cdc.gov/disasters/floods/pdf/after.pdf
- US EPA, Flood Cleanup and the Air In Your Home
  - http://www.epa.gov/mold/flood/flood_booklet_en.pdf
- US Department of Labor, Occupational Safety & Health Administration
  - http://www.osha.gov/OshDoc/floodCleanup.html
- University of Wisconsin Madison Extension 'Pesticide Storage Concerns During a Flood'
  - http://www.cdc.gov/nasd/docs/d001401-d001500/d001488/d001488.pdf
- Health and Safety Universal Precautions for Post-Flood Buildings
  - http://siri.uvm.edu/library/flood.html
- *Conserve O Grams*
  - http://www.nps.gov/history/museum/publications/conserveogram/cons_toc.html)
  - Health and Safety Hazards Arising from Floods http://www.nps.gov/history/museum/publications/conserveogram/21-01.pdf

The following guidance is collected from several sources (see above):

Preparing for floods

In order to be aware and prepare for possible flooding and prevent the area from accidental chemical spills, special attention should be paid to the types of chemicals used, stored and transported in the area. These chemicals might be industrial or commercial chemicals, pesticides, disinfection chemicals, paints, lacquers, diesel, gasoline, oils, chlorine, and metals, PAHs, PCBs, dioxins, liquid oxygen, waste, medical waste and corrosives. The source for chemicals contaminating the floodwater might be also from the remobilization from the soil.

In case of flooding the chemicals inventory in different sites could provide the information which chemicals might get in contact with flooding water. This information is for importance to the rescue and cleaning groups and the inventory can be done in different sites:

- Industry sites, uses, stores, transportation and processes
- Agricultural use, stores, transportation and use
- SME's use, stores and transportation
- Gasoline stations (underground fuel tanks) and oils
- Laundries and dry cleaning using and storing chemicals
- Hazardous waste sites

When making the preventing plan

- Purchase chemicals only for a single season (e.g. pesticides) or a reasonable short period.
- Store chemicals preferably above the (frequent) flood level or above the ground when possible.
- Develop an emergency response plan.

During and after flooding

Cleanup procedures after the flooding might vary very much depending on the area and which facilities are available e.g. fire brigades with proper instructions and protective measures.

Chemical contamination

- Use extreme caution in the area of flood and be aware of potential chemical hazards. Flood waters may have may have buried or moved hazardous chemical containers or other industrial chemicals from their normal storage places.
- There might be danger out of all gas lines and oil tanks, if not broken, but leaking.
- There might be danger of fires and explosions (e.g. tanks from gas grill or household propane tanks).
- Car batteries can cause electrical danger and danger of acid spills.
- Portable generators, grills, camp stoves or other gasoline, propane or natural gas devices should not be used indoors for heating or boiling water because this might lead to carbon monoxide poisoning.
- Consider all unusual odours or irritation of the skin and mucous membranes as to be signs of toxic chemical exposure, unless proved otherwise. Note also, that chemicals don't have odours that warn of their presence.
- Gardening chemicals and other household chemicals used in garages and cellars might cause harm.
- Protective measures should be used until the hazard is proven to not exist.
- Consider all pooled water inside and outside the buildings to be biological or chemical exposure hazard, unless proven otherwise by qualified personnel.
- Combustion of different equipment destroyed by the flood can also cause chemical contamination.
- Be aware of the possible hazard of the building materials which have been devastated during flooding.
- Children should not be allowed to play in flood waters or with toys that have been in contact with flood waters.

Cleanup and decontamination recommendations

Assume that any water in flooded or surrounding areas is not safe unless the local or state authorities have specially declared it to be safe.

- Crucial information is which chemicals were involved in flooding (oils, chlorine, pesticides, disinfection, very reactive chemicals, possibility of carbon monoxide poisoning, etc.).
- All the chemicals should be moved as soon as possible out from the water.
- All the damaged chemicals including the household chemical should be destroyed in the best possible way.
- Cleanup workers may need to use special chemical protective outer clothing and goggles, plastic or rubber gloves, safety boots and other protective clothing and respirators to avoid skin contact and inhalation of vapours.
- Maintain good hygiene during cleanup operations.
- Surfaces need to be cleaned and decontaminated.
- Do not mix detergents with chlorine based bleaches as this may release hazardous fumes.

Typical possible symptoms

- Eye, nose, throat, upper respiratory tract, and skin irritation.
- Flu like symptoms.
- Central nervous system depression, fatigue, loss of coordination, memory difficulties, sleeplessness, mental confusion.
- Chronic effects depend on the extent and the duration of exposure.
- Headache, nausea, diarrhoea, sweating, breathing difficulty and tremors or convulsions (especially in relation to pesticide poisoning).
- Shortness of breath, chest pains, swelling of abdomen (asbestos exposure).
- Fatigue, depression, heart failure, abdominal pain, anaemia, kidney failure (lead poisoning).
- Dizziness, chronic headaches or nausea, excessive tiredness, cherry red skin colour (carbon monoxide poisoning which can lead to sickness or death).
- Medical first aid treatment and medical advice should be present.
- Anyone who develops unusual symptoms should seek immediate medical attention.

Conclusions and best practices subsequent to floods to prevent human disease due to chemicals

In order to prevent human diseases due to chemical hazards during and after floods, the knowledge which chemicals are possibly present in the flooded area is for utmost importance. Beforehand made inventories would facilitate the plan how to rescue and how the cleaning work can be planned and done in a proper way. When chemicals are stored in a way, that possible flooding and especially in the frequent flooding areas the 'normal' level can be taken into account. When planning the storing of chemicals, the turn over rate can be set so, that chemicals are stored only for reasonable short periods and amounts.

Guidance can be prepared concerning chemicals in floods, at least for the most common chemicals in general and those typical in the area. Guidance to use personal protective equipment (boots, gloves, goggles, protective clothing, respiratory protection) can also be prepared taking into account the circumstances in the country and area.

General and detailed information concerning the safe use of chemicals can be provided to citizens as an everyday basis. The better people understand the dangers and safe use if the chemicals which they use and store e.g. in their homes, gives better possibilities to manage the situation also if flood occurs.

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