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CONTINGENCY PLANNING IN THE MEDITERRANEAN FOR SANITATION SYSTEMS DURING EXTREME WEATHER EVENTS

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EXECUTIVE SUMMARY

In the Mediterranean region, the consequences of global climate change are forecasted to be particularly severe, increasing the already existing water stress in the region. Increased average air temperatures, high variability in precipitation and extreme weather events (floods and droughts) are considered to be the main consequences. The increase in the air temperature is expected to result in rise of sea level, increase of surface waters' temperatures and increase of the incidence and extent of infectious diseases. The high variability in precipitation is possible to affect the river runoff (discharges), the water levels in lakes, reservoirs and wetlands, and the incidence and extent of infectious diseases. Extraordinary strong flash rains or long periods of drought are expected to be more frequent and intense.

The scope of the study is to present a systematic procedure for the formulation of an efficient and effective contingency plan (CP) for sanitation systems, i.e. the sewerage system and the wastewater treatment plan (WWTP), to face the consequences of an extreme weather event. Basic information on CPs, which is their scope and their stages of development are described. In the analysis the foreseeable emergencies are related to extreme weather events. CPs could help prevent and manage incidents possibly encountered in sanitation systems due to extreme weather events that could result in environmental impacts.

The main aspects of floods and droughts may cause a series of impacts - consequences on the sanitation systems. The most important aspects of storms, heavy rainfall events and flood events are the increased runoff, the sea level rise, floods and storm surges. The main aspects of droughts or prolonged periods without any rainfall are the decreased water flow rates in rivers and water levels in lakes and reservoirs, decreased water flow rates in sewers, decreased water flow rates in the WWTP and decreased levels of aquifers. Their main aspect details and impacts of extreme weather events on WWTPs are discussed. For example, a flood event will result in increased pollution of surface waters. The main consequence of the increased pollution of surface water bodies that are used for effluent discharge is that there will be a demand for lower concentration of pollutants from the WWTPs, i.e. for increased efficiency of WWTPs (impact on WWTP).

The subject of risk analysis that focuses mainly on the formulation of a risk matrix and the assessment of consequences is presented and the use of mathematical models is discussed. For the assessment of the risk of environmental harm, the Environmental Harm Risk Matrix (EHRM) is suitable for use in any situation, including the Mediterranean region. After the environmental hazards at a site have been identified and documented in a TAI (table of aspects and environmental impacts), they can be assessed using risk analysis. Risk analysis allows hazards to be ranked based on the level of risk, and determines which hazards present a big enough risk to consider risk treatment. Assessing the level of harm, to either human health or well-being or to the natural environment, can be a complex issue. Floods and droughts may cause environmental harm in many different ways, at a range of temporal and spatial scales and to a broad range of receptors. Changes in quantity and timing of precipitations (rainfall intensification, flash floods, long dry periods), the air temperature rise, the sea level rise and the frequency of the extreme weather events that occur more frequently are the basic factors to consider in order to assess the impacts of floods and droughts on the sanitation system. There is no simple formula for quantifying the degree of harm that can be applied to all situations. The Source-Pathway-Receptor-Consequence (S-P-R-C) model, which is a simple conceptual model for representing systems and processes that lead to a particular consequence, is described. Assessment of likelihood is a very important matter. The level of risk is based on the likelihood of the consequence, not the likelihood of the aspect. This is because the probability of an aspect does not necessarily equal the probability of the environmental consequence (or impact) that can be caused by the aspect. The description of the systems with accuracy is difficult and consequently the Knowledge of the system and the use of mathematical models and GIS are

very important. It is nowadays possible to use mathematical models that can simulate the hydraulics (or hydrodynamics) and water quality of a sanitation system (including the sewerage system and the WWTP) with reasonable accuracy. Model simulation can be performed for various scenarios of environmental conditions; these conditions may include “expected” emergency situations due to extreme weather events. The results of the models can be presented in various forms; often detailed GIS maps are used.

The main actions for the treatment of risk of the impacts are presented, including the recovery of the sanitation system after the extreme weather event of flood. A series of general actions for risk treatment against floods and droughts is described. The actions can be preventive or operational-protective. The main actions against the impacts include maintenance, crisis and emergency programs. Crisis and emergency plans provide operators with management rules and levels of critical indicators that enable them to recognize the potential threat and enable them to respond on time and correctly to the potential emergency situation. Plans should be regularly updated and stuff should be duly educated.

1 INTRODUCTION

1.1 Main consequences of global climate change

In the Mediterranean region, the consequences of global climate change are forecasted to be particularly severe, increasing the already existing water stress in the region.

Climate change is likely to lead to further environmental degradation jeopardising directly or indirectly social cohesion, well being and quality of life as well as security in the immediate future. The consequences are expected to be more important in the Mediterranean region where water resources are already scarce and water demand is rapidly increasing due to demographic pressure, urbanisation, tourism and development needs in general (http://www.minenv.gr/ medeuwi/download/Theme_2_Climate&Water_%20150708.pdf).

The main consequences of Global Climate Change are the following:

1) increased average air temperatures,

2) high variability in precipitation, and

3) extreme weather events.

1.2 Increased average air temperatures

1.2.1 Description, estimations and effects

Rise in average air temperatures has already affected the environment. Some observed changes include shrinking of glaciers, thawing of permafrost, later freezing and earlier break-up of ice on rivers and lakes, lengthening of growing seasons, shifts in plant and animal ranges and earlier flowering of trees (IPCC, 2007). If current trends in emissions of greenhouse gases continue, global temperatures are expected to rise much faster over the next century than over any other time during the last 10,000 years.

The Intergovernmental Panel on Climate Change (IPCC, 2007) estimates that for increases in global mean temperature of less than 1-3°C above 1990 levels, some places and sectors will see beneficial impacts while others will experience harmful ones. Some low-latitude and polar regions are expected to experience net costs even for small increases in temperature. For increases in temperature greater than 2-3°C, the IPCC says it is very likely that all regions will experience either declines in net benefits or increases in net costs. “Taken as a whole,” the IPCC concludes, “the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time.”

Mediterranean impact

Significant uncertainties surround predictions of regional climate changes, but it is likely that the Mediterranean region will warm significantly. An indication of the scale of possible changes is given by one scenario based on the output from four climate models. This suggests that average temperatures could rise by over 4°C by 2100 over many inland areas and by over half of this over the Mediterranean Sea (http://www.greenpeace.org/).

Giannakopoulos et al (2005) performed a study to understand the impacts of a 2°C global temperature rise in the Mediterranean region, using:

1) The outputs of the high temporal resolution climate model HadCM3 (temperature, precipitation and wind daily outputs). HadCM3 is a coupled atmosphere-ocean general circulation model (GCM), consisting of an atmospheric GCM coupled to an

ocean GCM. HadCM3 was developed at the Hadley Centre and it was one of the major models used in the IPCC Third Assessment Report in 2001. Unlike earlier atmosphere-ocean GCMs does not need flux adjustment (additional "artificial" heat and freshwater fluxes at the ocean surface) to produce a good simulation. The model has been run for over a thousand years, showing little drift in its surface climate. The atmospheric component of HadCM3 has 19 levels with a horizontal resolution of 2.5° of latitude by 3.75° of longitude, which produces a global grid of 96 x 73 grid cells. This is equivalent to a surface resolution of about 417 km x 278 km at the Equator, reduced to 295 km x 278 km at 45° of latitude. Thus the model geography is much simpler than the real-world geography. The oceanic component of HadCM3 has 20 levels with a horizontal resolution of 1.25 x 1.25°. The choice of HadCM3 over the other GCMs was made mainly because of the availability of daily data in HadCM3 (which is fundamental for the study of extremes in a region such as the Mediterranean) over the desired time period of the 2^{o}C global temperature rise.

2) The IPCC SRES A2 and B2 emission scenarios. The SRES scenarios were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions. The SRES team defined four scenarios labelled A1, A2, B1 and B2, describing the relationships between the forces driving greenhouse gas and aerosol emissions and their evolution during the 21st century for large world regions and globally. A2 scenario regarding a very heterogeneous world with continuously increasing global population and regionally oriented economic growth. B2 scenario regarding a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development (http://sedac.ciesin.columbia.edu/ddc/sres/).

The study focused on the period 2031-2060 centred on the time that global temperature is expected to reach 2^{o}C above pre-industrial levels and its main conclusions were the following:

1) A global temperature rise of 2°C is likely to lead to a corresponding warming of 1-3 °C in the Mediterranean region.

2) The warming is likely to be higher inland than along the coast.

3) The largest increase in temperature is expected to take place in the summer, when extremely hot days and heat-waves are expected to increase substantially, especially in inland and southern Mediterranean locations.

The increase in the air temperature is expected to result in

1) rise of sea level,

2) increase of surface waters' temperatures, and

3) increase of the incidence and extent of infectious diseases.

1.2.2 Rise of sea level

One of the most severe effects of global warming is the rise of the sea level as oceans expand and glaciers melt due to increase in temperature. Around much of the Mediterranean basin, sea levels could rise by close to 1 m by 2100. As a consequence, some low-lying coastal areas would be lost through flooding or erosion, while rivers and coastal aquifers would become more salty. The worst affected areas will be the Nile Delta, Venice and

Thessaloniki where local subsidence means that sea levels could rise by at least one-and-a-half times as much as elsewhere (http://www.greenpeace.org/).

Results from the HadCM3 give a projection of a global rise in sea level of 21 cm by the 2050s due to rise in greenhouse gases from human activities (IPCC, 2001). This estimate includes direct prediction of thermal expansion combined with estimates of land-based ice-melt. However, global mean sea level rise does not manifest itself uniformly around the world. Regional variations in atmospheric circulation, ocean circulation and warming rates and the interactions between them have led to significant deviations of regionally sea level change from the globally averaged trend. Model projections of regional sea level patterns show very little agreement. For the Mediterranean, the values range from 1 to 2cm of regional sea level rise per 1 cm of global sea level rise (IPCC, 2001). This is due to the low tidal range in the Mediterranean combined with the limited potential for wetland migration. The most vulnerable region seems to be the Southern Mediterranean from Turkey to Algeria where flooding impacts can occur particularly in deltaic countries (such as Egypt).

1.2.3 Increase of surface waters' temperatures

The temperatures of rivers, lakes and reservoirs will be affected by the increase in the air temperature; however, this effect is not homogeneous on all surface waters. Indeed, surface waters' temperature depends on the air temperature, but also on residence times, depth, flow and wind, and it is expected that higher water temperatures might occur in stagnant waters (heat waves). Climate change can also increase the resident times of surface waters in the summer season as a consequence of less precipitations and higher evaporation rates (summer droughts) (Scijven and de Rosa Husman, 2005).

The increase of water temperature may cause changes like

1) movement of freshwater species northwards and to higher altitudes,

2) alterations in life-cycle events (earlier blooms up of phytoplankton and zooplankton), and

3) increase of harmful cyanobacteria in phytoplankton communities with consequent raising of threats for lakes ecological status and of risks for human health.

1.2.4 Increase of the incidence and extent of infectious diseases

Higher air temperatures would increase the incidence and extent of infectious mosquito-borne diseases, such as malaria, dengue fever and yellow fever. Elementary models suggest that higher global temperatures will enhance their transmission rates and extend their geographic ranges. In particular, temperature affects mosquito-borne pathogens' rate of multiplication in the insect. In turn, this affects the rate at which the salivary secretions become infected, and thus the likelihood of successful transmission to another host. Temperature may also modify the growth of disease as biting rates alter, as well as affect population dynamics and alter the rate at which they come into contact with humans. Finally, a shift in temperature regime can alter the length of the transmission season (http://www.who.int/globalchange/publications/climatechangechap6.pdf). There are transmission models that predict the impact of climate change on mosquitoes' transmission dynamics. The climate change is taking into account in these models via the increase of temperature which has an effect on the extrinsic incubation period—the time taken for the pathogen to develop in the mosquito until the insect becomes infective (http://www.ncbi.nlm.nih.gov/pmc/articles/ PMC1240549/pdf/ehp109s-000141.pdf).

Schistosomiasis, caused by parasitic worms, is also expected to increase since the infection rates increase as temperature rises (http://www.springerlink.com/ content/ l618677705577364/fulltext.pdf).

1.3 High variability in precipitation

1.3.1 Description, estimations and effects

Precipitation changes, which are also very important to consider when assessing climate change effects, are more difficult to predict. Whether or not rainfall will increase or decrease remains difficult to project for specific regions. The outlook for precipitation is much less certain, but most projections point to more precipitation in winter and less in summer over the region as a whole.

A common feature of many projections is declining annual precipitation over much of the Mediterranean region south of 40 or 45° N, with increases to the north of this. Even areas receiving more precipitation may get drier than today due to increased evaporation and changes in the seasonal distribution of rainfall and its intensity (http://www.greenpeace.org/). Over the same period, annual precipitation is projected to decline by 10 to 40 percent over much of Africa and south-eastern Spain, with smaller - but potentially significant - changes elsewhere.

1.3.2 Effects

The high variability in precipitation is expected to affect

1) the river runoff (discharges),

2) the water levels in lakes, reservoirs and wetlands, and

3) the incidence and extent of infectious diseases.

By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics. Many semi-arid and arid areas (e.g., the Mediterranean Basin, western USA, southern Africa and north-eastern Brazil) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change (high confidence).

The average run-off in southern European rivers is projected to decrease due to increasing temperature and decreasing precipitation. In particular, some river basins in the Mediterranean, which already face water stress, may see marked decreases of water availability.

Changes in river flows, as well as lake and wetland levels, due to climate change depend primarily on

1) changes in the volume and timing of precipitation,

2) crucially, whether precipitation falls as snow or rain, and

3) changes in evaporation affect river flows.

Several hundred studies of the potential effects of climate change on river flows have been published in scientific journals, and many more studies have been presented in internal reports. Studies are heavily focused towards Europe, North America and Australasia, with a small number of studies from Asia. Virtually all studies use a catchment hydrological model driven by scenarios based on climate model simulations, and almost all are at the catchment scale. The few global-scale studies that have been conducted using both runoff simulated directly by climate models and hydrological models run off-line show that runoff increases in high latitudes and the wet tropics, and decreases in mid-latitudes and some parts of the dry tropics.

1.4 Extreme weather events – Floods and droughts

1.4.1 Description, estimations and effects

The climate change inevitably leads to changes in weather conditions in affected regions. Extraordinary strong flash rains or long periods of drought are expected as a result of the increase of average temperature, decrease of precipitation amount and its different spread out during the year. The Mediterranean basin is considered to be one of the most sensitive areas regarding to global warming and future climate extreme conditions (floods and droughts) due to unregulated, high-density housing areas.

Mediterranean Europe has already been suffering major damaging floods in the recent years. Although the floods cannot be attributed to global climate change exclusively, an increasing risk of flooding in the region is expected under climate change in combination with changes in river management, increased urbanisation of former floodplains, deforestation of upstream mountainous areas and further enhancing local rainfall run-off which also affect flood generation. Between 1975 and 2001, 480 extreme events had occurred in the Mediterranean. The countries reporting the heaviest toll in terms of victims were Turkey, Italy, Algeria, Greece and Egypt. Catastrophic floods attendant upon violent rainfall, and further aggravated by deforestation and construction on slopes, constitute a major risk for a great number of Mediterranean cities in Spain, France, Italy, Algeria, etc. The floods that struck Algiers in 2001 (920 dead and 50.000 disaster victims) and other very fatal disasters of the same type are likely to be more frequent and violent. These events will induce undoubtedly very high costs for the Mediterranean region (http://www.planbleu.org/publications/changement_clim_ energie_med_EN.pdf).

Extreme or/and prolonged rainfalls cannot only cause floods but are also the dominant driving mechanism for many forms of slope instabilities, through water loading in soils beyond a critical threshold, or through excessive runoff that will lead to rapid surface erosion and debris flows. Extremes of temperature could also contribute to slope instability events, notably through repetitive freeze-thaw mechanisms at high elevations that tend to weaken rocks by progressively enlarging fractures. In addition, permafrost degradation in high mountains resulting from milder atmospheric temperatures may contribute to slope instabilities by reducing the cohesion of slope material currently embedded within subsurface ice. This situation is expected to cause higher peak floods in streams or excessive discharges in inappropriate sewage or drainage ducts that are likely to divert sudden flows at the surface of slopes through manholes or pipe failure and thus generate destructive mud flows, if specific retention works are not foreseen (http://pentes-tunnels.eu/_enseignement /cours_RMF_2A/papier_xian/ 013.pdf). A rainfall-induced landslide occurred on March 4th of 2005 along the northern slope of the Monte Sant'Angelo di Cava mountain, located in the Nocera Inferiore town, in Italy. The "Centro Euro-Mediterraneo per i Cambiamenti Climatici" carried out numerical analyses aimed to simulate this event using Transient Rainfall Infiltration and Grid-based Regional Slope-stability (TRIGRS) program (Baum et al., 2002). TRIGRS requires detailed information on rainfall records, topography, soils properties, boundary conditions (depth of the lower impervious bedrock), and initial hydraulic conditions http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1370852).

On the other hand, major drought episodes are also projected to become more frequent with particularly intense summer droughts. Increase in drought periods manifested by an expected higher frequency of days during which the temperature would exceed 30°C (Giannakopoulos et al. 2005). This may be further exacerbated because of an increasing demand for water as a result of elevated temperatures. Worst hit is expected to be Cyprus, Malta, Greece, Italy (South), Portugal and Spain with an increase in frequency and severity of droughts and water scarcity. Heat waves will affect tourism activities as well as people's health and enhance energy consumption for cooling purposes. During the period 1952 to 1992, the number and frequency of heat waves affecting the Mediterranean region increased severely. The early 1990s were notable for recurrent droughts while the drought of 2005 was the worst for large parts of the continent but especially bad in the Mediterranean region e.g. the capacity of the Spanish reservoirs has been at 61.3% of the total between 1995 and 2005, during the drought of 2005 however, the water level declined considerably to an average of 40% and the fish mortalities increased (http://assets.panda.org/ downloads/ wwf_drought_med_report_2006.pdf).

Both droughts and floods are expected to affect human health and cause alterations in the ecology. An increase in the frequency and severity of heat waves would both increase illness and death rates. Some of the most serious effects may be felt in large cities, where extreme heat could aggravate local pollution problems and increase the incidence of respiratory illness. The sensitivity of populations in the Mediterranean region to such an outcome is highlighted by conditions in Athens in June to August 1993, where a combination of pollution and high temperatures during a heat wave caused more than a thousand people to seek medical attention in Athens. On the other hand, increases in storms or intense rainfall would increase death and injury rates. Torrential rain and the floods and/or destruction associated with it is already responsible for deaths in Mediterranean countries. Extreme weather events are also expected to decrease food production and therefore prices will become higher. As a result malnutrition and hunger could cause various health problems. The most severe problems are likely to be faced by those countries which already have the biggest problems today – notably those in North Africa and the near East. In these areas, child mortality rates among under-fives are already average six times higher than rates in southern European countries http://www.greenpeace.org/international/Global/international/planet-2/report/ 2006/ 3/climate-change-and-the-mediter.pdf.

Climate change will also indirectly affect ecosystems, for instance, an increase frequency of droughts might decrease the ability of trees to resist pests. Many valuable ecosystems could be lost as species fail to keep up with the shift in climate boundaries. Wetland sites will face the dual threats of drying out. Up to 85% of wetland sites in southern Europe could disappear with a 3 to 4°C rise in temperatures. In Tunisia, for example, rising temperatures could contribute to the loss of all food plants and breeding waterfowl and the disappearance of nationally important fisheries (http://archive.greenpeace.org/climate/science /reports/ fulldesert.html).

1.5 The present work

The scope of this work is to present a systematic procedure using the available literature for the formulation of an efficient and effective contingency plan (CP) for sanitation systems, i.e. the sewerage system and the wastewater treatment plant (WWTP), to face the consequences of an extreme weather event.

The present report consists of 6 chapters. In Chapter 1 (present chapter) the main consequences of global climate change are described, including the extreme weather events that are the floods and droughts. Chapter 2 deals with the basic information on CPs, which are their scope and their stages of development. In Chapter 3 the main aspects and impacts-consequences of floods and droughts are described. Chapter 4 is a short presentation of the subject of risk analysis that focuses mainly on the formulation of the risk matrix and the assessment of consequences; for the latter the use of mathematical models is discussed. In Chapter 5 the main actions for the treatment of risk of the impacts (described in chapter 3) are presented, including the recovery of the sanitation system after the extreme weather event of flood. Chapter 6 contains a short list of conclusions. A list of references is attached in the end of this report.

2 CONTINGENCY PLANS FOR SANITATION SYSTEMS

2.1 Introduction

Wastewater is hazardous to the environment, especially to inland, marine and ground waters. Therefore, it needs to be carefully managed by WWTP managers.

Contingency Plans (CP) are an important tool for responsible wastewater management (SAEPA, 2009). A CP is defined as a plan of action to be taken in the event of foreseeable emergencies that may involve the risk of serious or material environmental harm. In the present work the foreseeable emergencies are related to extreme weather events.

In the present chapter the main characteristics of CPs for sanitation systems are described based

1) mainly on a relatively recent document published by South Australian EPA (SAEPA, 2009):

   South Australian E.P.A., SAEPA (2009). EPA Guidelines, Contingency plans- a guide for wastewater producers and wastewater treatment plant operators. Available at: http://www.epa.sa.gov.au/xstd_files/Waste/ Guideline/ guide_contingency.pdf.

2) and other relevant documents that are included in the list of references in the end of the report, mainly the following (DSP,2004):

   Sewage Treatment Divisions One & Two, Drainage Services Department, DSP (2004). Contingency plan for incidents possibly encountered in sewage treatment facilities having a potential of generating an environmental nuisance. Available at: http://www.epd.gov.hk/eia/register/ report/eiareport/eia_0972004/pdf/eia2/app4.5. pdf.

The information provided in SAEPA (2009) regarding CPs is used after the required modifications and adjustments to the case of extreme weather events.

2.2 Scope of contingency plans

CPs for incidents possibly encountered in sanitation systems due to extreme weather events help prevent and manage these incidents that could result in environmental impacts, such as:

1) environmental harm, e.g. soil, surface or groundwater pollution,

2) environmental nuisance, e.g. excessive odor, noise, dust or smoke, and

3) unacceptable risk to public health.

These CPs can:

1) provide clear guidance during extreme weather events that may cause incidents like accidental spillages, equipment or plant failure. During these situations things are usually out of control and it is often not a good time for decision-making. The most effective way to prevent an incident is to eliminate the hazard. However, sometimes this option is not possible or is unreasonably expensive. In this case, where the hazard and subsequent risk/s remain, CPs can be used to manage the consequences and minimize the harm caused,

2) assist managers in meeting their general environmental duty and other relevant legislation requirements, and

3) support managers in best management practice by providing tools to assist in environmental management, and demonstrating to stakeholders their commitment to environment protection.

According to DSP (2004) a CP for WWTPs is drawn up to provide guidelines to all plant staff at various sewage treatment facilities in dealing with different types of incidents, which have a potential of generating an environmental nuisance and possibly polluting the stream courses, harbors or beach water. Flowcharts, lists of emergency equipment, lists of contact persons and telephone numbers and notification forms can be constructed to assist plant staff to respond promptly in handling the incidents.

A CP has the following objectives:

1) to avoid and, if not possible, to minimize environmental impact to the surrounding area and water,

2) to notify the responsible services on incidents of polluting the environment according to the requirements of the discharge licenses,

3) to co-ordinate and provide essential information to other relevant government departments to facilitate planning and decision making,

4) to enable the responsible ministry (e.g. Ministry of Defense) to respond promptly to the public enquiries and media and to provide accurate information on incidents that may have environmental impacts on surrounding areas or waters,

5) to seek assistance from the relevant works agents and authorities for emergency and repair services,

6) to minimize damages to the affected plant, and

7) to ensure the emergency procedures required are organized and implemented in an orderly manner.

2.3 Development of a contingency plan

The development of a CP is performed following a series of 6 steps that are described below.

1) <u>Step 1. Identification of hazards and development of a table of aspects and environmental impacts (TAI)</u>.

   The first step towards the formulation of a CP is the identification of hazards and the gathering of all necessary information to enable the development of a table of aspects and (environmental) impacts (TAI). This register may contain the (1) aspect, (2) the aspect details and (3) the subsequent impacts.

   For example, the “extreme weather events”, i.e. “floods and draughts” can be considered as hazards. The “inundation of wastewater storage, treatment and disposal system by floodwaters” can be one of the aspect details of the aspect “floods”, and an environmental impact associated with the above-mentioned aspect is the “pollution of surface waters”.

2) Step 2. Performance of risk analysis.

After the formulation of the TAI, a risk analysis can be used to prioritize risks that require urgent measures, ideally utilizing a process that engages operators and staff of the sanitation system.

For each aspect and impact, the likelihood of an environmental incident occurring and the level of impact (consequence) can be assessed as:

Risk = consequence x likelihood

This is done using a Risk Matrix (RM), such as the version of the SAEPA (2009) that is described in more detail in Chapter 4. The risk can then be prioritized to determine the type and urgency of action that is required.

3) Step 3. Development of actions for risk treatment.

Once a high or significant risk is identified, appropriate risk treatment needs to be developed. The recommended hierarchy for risk treatment from highest to lowest is shown below.

a. eliminating the hazard, e.g. replace the plant equipment of the WWTP,

b. reducing the hazard, e.g. modify plant or equipment, install controls or alarms, build in redundancy or backup systems, engage the services of qualified contractors to manage the system,

c. blocking the pathway, e.g. apply flood protection measures, such as installation of levees and sea walls around WWTPs, and

d. administrative control, e.g. update or develop methods or procedures.

For the example mentioned in step 1, one of the possible risk treatment actions is the “installation of storm-water diversion systems”.

Eliminating the hazard is the most effective form of risk treatment, although at times this may not be feasible or requires high capital investment. For example, in an old sanitation system the civil engineering structures cannot be adapted in an economically feasible way to face changes in flow rates and pollution loads due to extreme weather events. Thus, in old sanitation systems the hazard of flooding of the system can be reduced, but not eliminated.

In such cases, where the elimination of the hazard is not practically feasible, a CP utilizing the other risk treatment options described above may be the best alternative.

Other possible courses of action include:

a. a preventative maintenance program, e.g. inspection frequency based on run-time hours,

b. monitoring programs, and

c. training programs, e.g. staff programs, new employee/contractor site induction.

4) Step 4. Drafting the CP.

A CP can only be effective if

a. it is clear and concise,

b. addresses specifically all the significant risks, and

c. describes clearly (e.g. locations etc.) the proposed risk treatment actions can be objectively measured or demonstrated.

Persons implementing the CP must be able to understand and execute these actions at indicated timelines or when the need arises.

5) Step 5. Management endorsement.

The CP should be approved by the responsible management body prior to its implementation.

6) Step 6. Training, implementation and review.

For the CP implementation to be effective, appropriate training will need to be provided to both permanent and contractual staff on the actions to be undertaken in the case of an extreme weather event.

Once an incident has occurred, appropriate risk treatment will need to be incorporated in the CP to prevent similar incidents occurring in future.

It is also recommended to test the risk treatment actions (e.g. prior to vintage, plant or equipment start-up), where possible to ensure that they are still appropriate to address the risks.

The CP must be reviewed and updated:

a. regularly at nominated intervals preferably at least once every three years,

b. in response to any alterations to processes and infrastructure that may result in increased risk of environmental harm,

c. in response to issues identified from process monitoring or testing, and

d. in response to environmental incidents or serious complaints.

3 ASPECTS AND IMPACTS OF EXTREME WEATHER EVENTS

3.1 Introduction

The various aspects of extreme weather events may cause a series of impacts on the sanitation systems and the environment. These impacts can be

1) Directly on the environment and then indirectly on the sanitation system, and

2) Directly on the sanitation system and then indirectly on the environment.

The resulting impacts are always site-specific and depend mainly on

1) the type of the sewerage system (combined or separate, and centralized or de-centralized local),

2) the characteristics of the WWTP (mainly the degree and methods of treatment), and

3) the environmental (usually local) conditions, mainly meteorological and hydrological conditions.

These impacts are explained in more details in the following paragraphs.

Combined sewer systems are designed to transport both storm water runoff and sewage in the same sewers. Besides the projected sewage flow, the size and characteristics of the watershed are the overriding design considerations for combined sewers. Often, combined sewers cannot handle the volume of runoff, resulting in combined sewer overflows and causing water pollution problems in nearby water bodies.

Separate sanitary sewer systems have two sewer systems.

1) The first is designed to transport only sewage to a WWTP for treatment prior to its disposal.

2) The second is constructed to convey storm-water runoff directly to surface waters.

This type of sewer system is effective in controlling the flows to the WWTP. Problems could arise with misleading connections and also with high pollution of surface water from the first flush.

Most municipal sewer systems constructed today are separate sewer systems.

Although separate sewer systems are intended to transport only sewage, all sewer systems have some degree of inflow and infiltration of surface water and groundwater, which can lead to sanitary sewer overflows. Inflow and infiltration is highly affected by antecedent moisture conditions, which also represents an important design consideration in these systems.

In new housing developments or in rural areas, where no sewerage system existed before, separate systems are usually installed.

A centralized sanitation system is usually characterized by:

1) a large drained area with high share of built up area,

2) a main WWTP located centrally, and

3) several smaller WWTPs located in the city outskirts.

A decentralized and community-based sanitation system is usually characterized by:

1) small-sized networks and facilities with limited budget, and

2) equipment of medium technological level; thus during emergency situation it is less operative and effective.

Many rural settlements are not equipped by the sewer and WWTP. Wastewater disposal from households is secured by the small home WWTPs, septics or simply cesspools that are used for biological waste. When small home WWTPs are being designed for wastewater disposal, it is necessary to take into account the location of rural remote houses in flood prone areas.

In centralized systems, during an extreme weather event, such as a flood, the central WWTP may be out of order and all wastewater is discharged into the receiving water body without any treatment (practically) at one point, thus creating a very high point pollution. This unfavorable situation could have significant impact on surface water quality (see chapter 3.2).

In decentralised and community-based systems the impact of storm-water can significantly increase the water flow fluctuation during rainfall events. Thus, in such systems the construction of measures mitigating the water inflow to the WWTP is highly recommended, e.g. separation between sewer and rain water drainage networks, which is possible if suitable natural receiving bodies for storm-water discharges are available.

A WWTP is characterized by its degree or level of treatment. The main levels of treatment are:

1) Preliminary treatment,

2) Primary treatment,

3) Secondary or biological treatment,

4) Tertiary treatment; mainly Nitrogen and Phosphorus removal, and

5) Additional treatment for reuse of the effluent.

3.2 Aspects and impacts of floods

Storms, heavy rainfall events and flood events can be considered to have the following main three aspects:

1) Increased runoff,

2) Sea level rise, and

3) Floods and storm surges.

The above-mentioned three aspects may have the aspect details and impacts that are described below.

1) Increased pollution of surface waters.

Flooding may lead to contamination of waters with dangerous chemicals, heavy metals, or other hazardous substances, from storage or from chemicals already in the environment, such as pesticides. Furthermore, there is little published evidence demonstrating a causal effect of chemical contamination on the pattern of morbidity and mortality following flooding events (Euripidou and Murray, 2004); see http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch8s8-2-2.html for more relevant references.

Several studies have shown that contamination of freshwater by enteric pathogens is higher during the rainy season. In a study in the Netherlands (Schjven et al., 2005), one of the main conclusion was that increased precipitation in winter and more frequent heavy rain events in summer lead to peak concentrations of waterborne pathogens in surface waters that are several orders of magnitude above average levels.

Furthermore, increased water flows (due to storms) will displace and transport different components from the soil to water resources through fluvial erosion. Stormy rainfalls causing increased flooding run off, erosion and river discharges will have a major impact on the abundance of waterborne pathogens in bathing waters due to increased erosion of agricultural soils and the overflow of rural and urban sewage treatment systems. A lot of faecal pathogens will be washed into the bathing waters.

Therefore, the main consequence of the increased pollution of surface water bodies that are used for effluent discharge is that there will be a demand for lower concentration of pollutants from the WWTPs, i.e. for increased efficiency of WWTPs (impact IF1). As a result of the situation above, the pollution to the water course that is used for effluent discharge will increase (indirect effect; see chapter 3.1).

Moreover, as water pollution increases the amount of safe drinking water that humans are able to use will be reduced. As a result demand for clean drinkable water will rise.

2) Increased water levels of surface water bodies that are used for effluent discharge.

Floods result in increased water levels of surface water bodies that are used for effluent discharge. Thus, it will be required for a WWTP to raise the energy for effluent discharge to these water bodies (impact IF2). As a result of the situation above, the effluent discharge following the required specification will not meet the standards and pollution to the water course may increase, for example due to lower initial dilution of the disposed jet (indirect effect; see chapter 3.1).

3) Increased flow rates in sewers.

Usually, floods result in very large flow rates in sewers that cover the hydraulic capacity of sewerage systems. Moreover, during floods, surface water from the river can enter the sewer system through hydraulic connections between the river and the sewerage system, such as via combined sewer overflows, weirs, outlets and leaky sewage conduits.

In such cases flow velocities become very high, hydraulic retention times are very short and open channel flow can be transferred to flow under pressure (impact IF3). If flow rates in sewers or the units of a WWTP become extremely high, then flooding of the system may occur (possible indirect effect, see IF8) with subsequent increased water pollution of the surface water bodies (indirect effect).

4) Increased flow rates in WWTPs.

High flow rates in the sewerage system will be transferred to the WWTP. The higher flow rates will result in higher hydraulic loadings and lower hydraulic retention times of all units. This will lead to a significant reduction of the hydraulic and performance efficiency of units of the WWTP that are designed based on hydraulic loading and/or retention time, such as settling tanks and biological reactors (impact IF4). As a result of the situation above, the pollution to the water course that is used for effluent discharge will increase (indirect effect; see chapter 3.1).

5) Increased pollution loads in sewers.

Higher pollution loads due to runoff may create anaerobic conditions in sewers that may result to odor generation in sewers (impact IF5) and possibly in the neighboring residential areas (indirect effect; see also example in chapter 4.3).

It is noted that dilution due to higher flow rates may have a beneficial effect by balancing the increased loads.

6) Increased pollution loads in WWTPs.

High pollution loads in the sewerage system will be transferred to the WWTP. The higher pollution loads will result in higher pollution loadings, such as, to all units of the WWTP. This will lead to a significant reduction of the efficiency of units of the WWTP that are designed based on pollutant loading (mainly BOD loading and SS loading); these units are mainly biological reactors, such as anoxic tanks, aeration tanks, MBRs etc. (impact IF6). As a result of the situation above, the pollution to the water course that is used for effluent discharge will increase (indirect effect; see chapter 3.1).

Furthermore, it is noted that the increased pollution loads and increased flow rates may result in significant alteration of the pollutant concentrations that may also have an effect on the efficiency of the units of WWTP.

7) Increased levels of aquifers close to coastal areas.

High sea water levels due to sea storms may result in significant higher levels of groundwater levels and groundwater pollution (saline water intrusion). A possible consequence is the degradation of sewer conduits due to infiltration of saline water (impact IF7). As a result of the situation above, the pollution of groundwater will increase due to infiltration (indirect effect; see chapter 3.1).

8) Storm surges and flooding.

When flow rates in sewers or the units of a WWTP become extremely high (see IF3), then the sewerage system and/or the WWTP can be flooded. Also, in long highly fluctuating rivers, flood waves generated by intense rainfall can propagate quite rapidly, with potentially dangerous effects on sanitation systems along the river as well as downstream on areas not directly affected by storm events.

Therefore, sanitation systems (sewerage and WWTPs) can be flooded directly from the river or from the backwater in the surrounding area (impact IF8).

The main reasons for WWTP flooding are:

1) insufficient flood protection,

2) failure in the system,

3) abnormally high magnitude of the flood wave, or

4) damages caused by human errors that are due to the improper implementation of the crisis and emergency plan (see chapter 5.4).

As a result of the situation above massive escape of pathogenic bacteria and other dangerous microorganisms to surface water bodies or groundwater will occur and pollution loads discharged to water courses will be dramatically increase (indirect effect; see chapter 3.1).

Table 3.2-1: Register of aspects and impacts for hazard “floods”

Aspect	Aspect details	Impact to sewers	Impact to WWTPs	Impact to environment
Increased runoff	Increased pollution of surface water bodies.		Demand for increased efficiency of WWTPs (IF1).	Increased pollution of surface water bodies that are used for effluent discharge (indirect effect).
Increased runoff	Increased water levels of surface water bodies that are used for effluent discharge.		Requirement for higher hydraulic energy of the effluent discharge (IF2).	Increased pollution of surface water bodies that are used for effluent discharge (indirect effect).
Increased runoff	Increased flow rates in sewers.	Higher velocities. Lower retention times. Pressure flow (IF3). Flooding may occur (see IF8).	Flooding may occur (see IF8).	Increased pollution of surface water bodies (indirect effect).
Increased runoff	Increased flow rates in WWTPs.		Reduction of the efficiency of WWTPs (IF4).	Increased pollution of surface water bodies that are used for effluent discharge (indirect effect).
Increased runoff	Increased pollution loads in sewers.	Odor generation in sewers (IF5).		Possible odor generation in residential areas (indirect effect).
Increased runoff	Increased pollution loads in WWTPs		Reduction of the efficiency of WWTPs (IF6).	Increased pollution of surface water bodies that are used for effluent discharge (indirect effect).
Sea level rise	Increased levels of aquifers close to coastal agricultural areas. Salt water intrusion.	Degradation of sewer conduits (IF7).		Water pollution of groundwater due to infiltration (indirect effect).
Flooding and storm surges	Flooding and storm surges	Over-flooding of units. Disruption of processes. Failure of electricity. (IF8)	Over-flooding of units. Disruption of processes. Failure of electricity. (IF8)	Increased pollution of surface water bodies (indirect effect).

3.3 Aspects and impacts of droughts

Droughts or prolonged periods without any rainfall can be considered to have the following main aspects:

1) Decreased water flow rates in rivers and water levels in lakes and reservoirs. Expected longer periods of droughts would lead to significant decrease in river flow.

2) Decreased water flow rates in sewers.

3) Decreased water flow rates in the WWTP.

4) Decreased levels of aquifers.

The above-mentioned four aspects may have the aspect details and impacts that are described below.

1) <u>Decreased water flow rates in rivers and water levels in lakes and reservoirs.</u>

Lower discharges of rivers and lower water levels in reservoirs and lakes will result in decreased dilution capacity and higher concentration of pollutants.
Therefore, the main consequence due to the increase higher concentration of surface water bodies that are used for effluent discharge is that there will be a demand for lower concentrations of pollutants from the WWTPs, i.e. for increased efficiency of WWTPs (impact ID1). This consequence would require increased WWTP's treatment efficiency and may even evoke stricter limits for discharge to water bodies in order to keep their current quality status (indirect effect).

Moreover, increased water pollution will result in higher water supply demands, as described in 3.2.

2) <u>Decreased water flow rates in sewers</u>.

Usually, droughts result in very low flow rates in sewers. Flow velocities become very low, hydraulic retention times are very high and sediment rates increase. This may result in formation of incrusts and sediments and partial or full blocking of pipes, thus reducing their hydraulic capacity (impact ID2). As a result of the situation above, significant problems would arise during the next high flow rate in the sewer (indirect effect).

3) <u>Decreased water flow rates in sewers</u>.

Increased quantities of sediments due to high sediment rates may lead to increased population of rodents. This would result in the presence of undesirable animals in the WWTPs that may affect the biological processes in the WWTPs (impact ID3). As a result of the situation above, the pollution to the water course that is used for effluent discharge will increase (indirect effect).

4) <u>Decreased water flow rates in sewers</u>.

Increased quantities of sediments and higher retention times in the sewers may lead to anaerobic conditions and the release of odors in the sewers and in the inlet pumping station and preliminary treatment of the WWTPs (impact ID4), and possibly in the neighboring residential areas (indirect effect; see also example in chapter 4.3).

Moreover, it is noted that odor problems may appear in channels and pipes connecting the units of the WWTPs, where uncontrolled anaerobic conditions may be created.

5) Decreased water flow rates in the WWTP.

The very low flow rates in the sewerage system will be transferred to the WWTP and will result in lower hydraulic and pollutant (mainly organic) loadings and higher hydraulic retention times of all units (tanks and biological reactors).

This effect combined with the increased incoming concentrations of pollutants may lead to reduction of the hydraulic and performance efficiency of units of the WWTP that are designed based on hydraulic loading, pollutant (mainly organic) loading and/or retention times; i.e. practically for all units of the WWTP (impact ID5).

This consequence will result in increased pollution to the water course that is used for effluent discharge (indirect effect).

6) Decreased levels of aquifers.

Decreased levels of aquifers close to coastal areas may result in salt water intrusion. A possible consequence is the degradation of sewer conduits due to infiltration of saline water (impact ID6; see also impact IF7). As a result of the situation above, the pollution of groundwater will increase due to infiltration (indirect effect).

3.4 Other aspects and impacts related to extreme weather events

Other aspects that are linked to extreme weather events, but not directly related to floods and droughts, are increased air, water and sewage temperatures.

These aspects are expected to have the following consequences:

1) Increased sewage temperatures result in faster biological processes. Thus,

   a. Higher oxygen requirements for biological oxidation and nitrification and higher aeration costs. Higher temperatures accelerate biological processes that demand oxygen (biological oxidation and nitrification). Consequently higher amounts of oxygen are required otherwise anaerobic conditions may develop. Moreover, in high temperatures oxygen solubility in water is lower.
   b. Lower requirements for sludge heating in anaerobic digesters and thus lower energy requirements. Digesters should be kept in constant temperature since this is a critical operational parameter of the process of anaerobic digestion. In case of increased sewage temperature, the required rise of temperature is smaller and thus the cost of the required energy is reduced.
   c. Higher risk for the creation of anaerobic conditions and odor generation in (a) the sewerage system and (b) the sewage and sludge retention units.

2) Increased air temperatures result in higher dust concentration and thus in higher costs of air filtration. In high temperatures humidity level is lower and consequently dust concentration increases and inhibits the filtering operation. To avoid pore-blocking air provided to filtrations should be increased.

Table 3.3-1: Register of aspects and impacts for hazard “droughts”

Aspect	Aspect details	Impact to sewers	Impact to WWTPs	Impact to environment
Decreased water flow rates in rivers and water levels in lakes and reservoirs.			Demand for increased efficiency of WWTPs (ID1).	Increased concentrations of pollutants of surface water bodies that are used for effluent discharge (indirect effect).
Decreased water flow rates in sewers.	Lower flow velocities. Increased sediment rates.	Formation of incrusts and sediments. Partial or full blocking of pipes. Reduction of the hydraulic capacity of pipes (ID2).		
Decreased water flow rates in sewers.	Lower flow velocities. Increased sediment rates.	Increased quantities of sediments. Increased population of rodents (ID3).	Undesirable animals in the WWTPs (ID3).	Increased pollution of the water course that is used for effluent discharge (indirect effect).
Decreased water flow rates in sewers.	Increased sediment rates. Higher retention times. Creation of anaerobic-septic conditions.	Unpleasant odor from sewers (ID4).	Unpleasant odor from WWTPs (ID4).	Possible odor generation in residential areas (indirect effect).
Decreased water flow rates in the WWTPs.	Higher concentrations of pollutants. Lower hydraulic loads. Higher hydraulic retention times. Changed organic loadings.		Possible negative effect on the efficiency of WWTPs (ID5).	Possible increased pollution of the water course that is used for effluent discharge (indirect effect).
Decreased levels of aquifers close to coastal areas.	Increased levels of aquifers close to coastal agricultural areas. Salt water intrusion.	Degradation of sewer conduits (ID6).		Water pollution of groundwater due to infiltration (indirect effect).

4 RISK ANALYSIS

4.1 The risk matrix

The information contained in the present chapter was obtained from the South Australian EPA (SAEPA, 2009) that has developed the Environmental Harm Risk Matrix (EHRM) shown in Figure 4.1-1 for the assessment of the risk of environmental harm. The EHRM is based on the definitions of environmental harm within the framework of the Australian Standard AS/NZS 4360:2004 Risk Management. This risk matrix is suitable for use in any situation, including the Mediterranean region, where the level of risk of environmental harm is to be assessed.

CONSEQUENCE							
Level 5 High-level serious environmental harm	A5	B5	C5	D5	E5	F5	G5
Level 4 Serious environmental harm	A4	B4	C4	D4	E4	F4	G4
Level 3 Material environmental harm	A3	B3	C3	D3	E3	F3	G3
Level 2 Environmental nuisance and default non-compliance	A2	B2	C2	D2	E2	F2	G2
Level 1 Minor consequence	A1	B1	C1	D1	E1	F1	G1
	Daily or more often	Once a week or more often	Once a month or more often	Once a year or more often	Once in ten years or more often	Once in 100 years or more often	Less often than once in 100 years
	LIKELIHOOD						

Figure 4.1-1: Environmental Harm Risk Matrix;
(Source: South Australian EPA (SAEPA, 2009)

After the environmental hazards at a site have been identified and documented in a TAI (see chapter 2.3), they can be assessed using risk analysis.

Risk analysis allows hazards to be ranked based on the level of risk, and determines which hazards present a big enough risk to consider risk treatment.

Risk = consequence x likelihood

The alpha-numeric codes are used to identify and record the location of a risk in the matrix. The red area signifies a risk that the EPA considers as significant enough to require appropriate risk treatment. The EPA calls these ‘priority risks’.

4.2 Assessment of consequence

4.2.1 General

Assessing the level of harm, to either human health or well-being or to the natural environment, can be a complex issue.

Floods and droughts may cause environmental harm:
a. in many different ways,
b. at a range of temporal and spatial scales, and
c. to a broad range of receptors.

To assess the impacts of floods and drought on the sanitation system and the environment, it is important to consider the following factors:
a. changes in quantity and timing of precipitations (rainfall intensification, flash floods, long dry periods),
b. air temperature rise,
c. sea level rise and the frequency of the extreme weather events that occur more frequently.

There exist many combinations of these factors and there is no simple formula for quantifying the degree of harm that can be applied to all situations.

However, the Source-Pathway-Receptor-Consequence (S-P-R-C) model provides an excellent tool for understanding the likely consequences of a flood or a drought and provides information to understand the linkage between hazard (floods or droughts) and risk.

4.2.2 The Source-Pathway-Receptor-Consequence (S-P-R-C) model

The Source-Pathway-Receptor-Consequence (S-P-R-C) model, which is shown in Figures 4.2-1 and 4.2-2, is essentially a simple conceptual model for representing systems and processes that lead to a particular consequence (http://www.floodsite.net/html/faq2.htm).

For a risk to arise there must be

a. a hazard that consists of a “source” or initiator event,

b. a “receptor”, and

c. a “pathway”.

The “source” is the origin of a hazard, such as a high rainfall, strong winds, or a surge that can create a flood (hazard).

The “receptor” refers to the entity that may be harmed, such as a property, people, a WWTP. For example, in the event of heavy rainfall (the source) flood water may propagate across the flood plain (the pathway) and inundate a WWTP (the receptor) that may suffer material damage and create water pollution (the harm or consequence). The vulnerability of a receptor can be modified by increasing its resilience to flooding.

The “pathway” is the route that a hazard takes to reach receptors. A pathway must exist for a hazard to be realized.

The "consequence" is an impact, such as economic, social or environmental damage/improvement that may result from a flood. It may be expressed quantitatively (e.g. monetary value), by category (e.g. High, Medium, Low) or descriptively (see Chapter 4.2.3).

A hazard does not automatically lead to a harmful outcome, but identification of a hazard does mean that there is a possibility of harm occurring, with the actual harm depending upon the exposure to the hazard and the characteristics of the receptor.

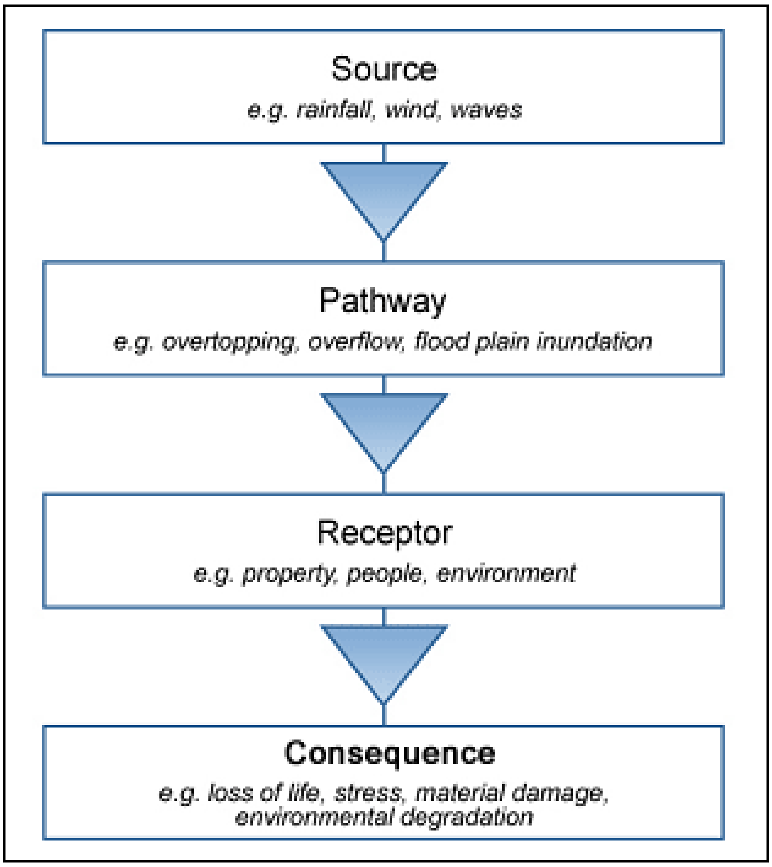

Figure 4.2-1: Flow chart of the S-P-R-C model
(Source : http://www.floodsite.net/html/faq2.htm)

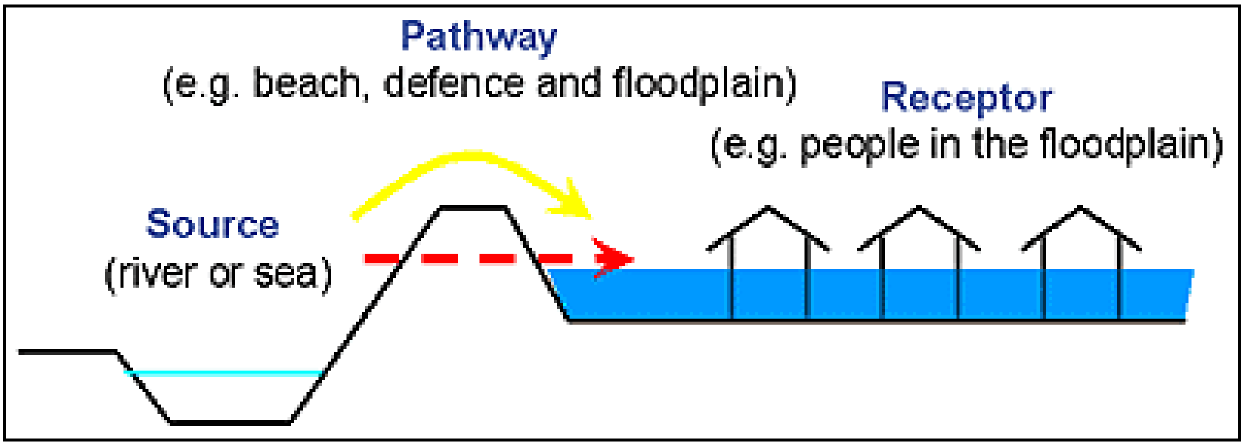

Figure 4.2-2: Schematic diagram of the S-P-R-C model
(Source : http://www.floodsite.net/html/faq2.htm)

4.2.3 Expression of the consequence

The consequence ratings in the risk matrix described in chapter 4.1 are based on the definitions of environmental harm that are found in SAEPA (2009).

1) Level 1: Minor consequence.

   Harm that is below the threshold of environmental nuisance is characterized as minor.

2) Level 2: Environmental nuisance and default level for non-compliance.

   Environmental nuisance is:

   (a) any adverse effect on an amenity value of an area that (a1) is caused by pollution, (a2) unreasonably interferes with, or is likely to unreasonably interfere with, the enjoyment of the area by persons occupying a place within, or lawfully resorting to, the area, or

   (b) any unsightly or offensive condition caused by pollution.

3) Level 3: Material environmental harm.

   Environmental harm must be treated as mild environmental harm if:

   (a) it consists of an environmental nuisance of a high impact or on a wide scale,

   (b) it involves actual or potential harm to the health or safety of human beings that is not trivial, or other actual or potential environmental harm (not being merely an environmental nuisance) that is not trivial, and

   (c) it results in actual or potential loss or property damage of an amount, or amounts in aggregate, exceeding approximately €3,600.

4) Level 4: Serious environmental harm.

   Environmental harm must be treated as serious environmental harm if:

   (a) it involves actual or potential harm to the health or safety of human beings that is of a high impact or on a wide scale, or other actual or potential environmental harm (not being merely an environmental nuisance) that is of a high impact or on a wide scale,

   (b) it results in actual or potential loss or property damage of an amount, or amounts in aggregate, exceeding €36,000.

5) Level 5: High-level serious environmental harm.

   A high level of serious environmental harm occurs if:

   (a) it involves actual or potential harm to the health or safety of human beings that is of a high impact and a wide scale, or other actual or potential environmental harm (not being merely an environmental nuisance) that is of a high impact and a wide scale,

(b) it results in actual or potential loss or property damage of an amount, or amounts in aggregate, exceeding €360,000.

4.3 Assessment of likelihood

Managing the risk of a flood event can be considered as a sequence of four activities:

1) detection of the likelihood of a flood forming (hydro-meteorology),

2) forecasting of future river flow conditions from the hydro-meteorological observations,

3) warning issued to the appropriate authorities and the public on the extent, severity and timing of the flood, and

4) response to the emergency by the public and the authorities.

Likelihood is the chance of an environmental impact (consequence) occurring. In the SAEPA (2009) risk matrix, likelihood is expressed as the time period an event is predicted to occur in, e.g. once a month or once a year.

The level of risk is based on the likelihood of the consequence, not the likelihood of the aspect. This is because the probability of an aspect does not necessarily equal the probability of the environmental consequence (or impact) that can be caused by the aspect.

For example:

1) A period of drought (hazard) results in decreased water flow rates in sewers (aspect) and increased sediment rates due to low velocities (aspect details).

2) Anaerobic-septic conditions are expected to be created in the sewerage system. Unpleasant odors will be emitted from the sewerage system and the units of preliminary treatment of the WWTP (consequence).

3) The likelihood of the sanitation system emitting odor may be equal to a certain value "a" that is related to the occurrence of drought (e.g. return period).

4) Odor emissions may impact on residents only when the wind is blowing towards the residential area. Therefore, the likelihood of an impact is the probability of the odor emission "a" multiplied by the probability of the wind blowing towards the local residents.

In some cases, however, the chance of an aspect will equal the chance of an impact. A spill of wastewater into a permanent river due to the failure of WWTP, for example, will always deplete oxygen leading to fish kills and the death of other aquatic organisms.

The Source-Pathway-Receptor-Consequence (S-P-R-C) model is a useful tool to help consider the likelihood of harm. However, to determine or estimate how the hazard impacts on the environment, a good knowledge of the system and the relationship between the factors and the conditions under which an aspect will cause harm.

If the system and the relationship between the aspect and the impact are well understood, the assessment of the likelihood of consequence is relatively simple.

If the system and the relationship between an aspect and an impact are not well understood, the assessment of the likelihood of a consequence is a more difficult task. In these cases, the estimation of the probability of a risk requires relevant past experience (use of information from the same or similar event that have occurred before) and personal judgment. The likely consequence level of an impact may be known from past experience.

Often, it may be necessary to estimate the consequence from knowledge of the system. Research of similar cases may provide useful information.

4.4 Knowledge of the system-Use of mathematical models and GIS

Nowadays, weather forecasts are detailed and precise. However, the exact determination of the extent of extreme weather events (such as a flash storm) and their impact on the sanitation system and the environment are practically not possible.

There is a lot of uncertainly in the description of the changes in quantity and timing of precipitations (such as rainfall intensification, flash floods and long dry periods), air temperature rise, sea level rise and higher frequency of extreme weather events (decrease in return period of extreme events). More difficulty is added to the description of a system, when the sewerage system is combined and centralized. The consequences of floods are not a temporary increased level of river or other surface waters during which the area in the proximity of the riverbed is flooded. The damage can be caused also by the water not being able to flow naturally away from any area or by the volume of rainwater exceeding the capacity of drainage system for a longer time.

In other words, the exact modeling of the system with the procedures described by the Source-Pathway-Receptor-Consequence (S-P-R-C) model is not yet feasible.

Despite the above-mentioned difficulties to describe the system with accuracy, it is nowadays possible to use mathematical models that can simulate the hydraulics (or hydrodynamics) and water quality of a sanitation system (including the sewerage system and the WWTP) with reasonable accuracy. Model simulation can be performed for various scenarios of environmental conditions; these conditions may include “expected” emergency situations due to extreme weather events. The results of the models can be presented in various forms; often detailed GIS maps are used.

Simulations using hydraulic models can provide the main hydraulic characteristics, which are the water elevations and flow velocities in the sewerage system (including complex networks), the units of WWTPs, and the neighboring areas and water courses for various scenarios involving a flood event or a drought period. Simulations with water quality models can provide the concentrations of pollutants and other water quality variables (such as DO) in the sanitation systems and the water courses.

These characteristics can be useful for design purposes and operation purposes, i.e. for (a) the design of actions against an extreme weather event prior to its occurrence, and (b) the performance of actions during an extreme weather event.

Some indicative applications of the models are the following:

1) Identification of critical locations or weak points of the sanitation system during droughts, where extensive sedimentation is expected to occur that will eventually lead to anaerobic conditions or blocking of the pipes or units.

2) Identification of critical locations or weak points of the sanitation system during floods, where the hydraulic capacity is expected to decrease that will eventually lead to flow in closed conduits.

3) Identification of risk areas during floods with information on their extent (inundation areas), water depth and duration for various flood scenarios.

4) Estimation of the response of the units of a WWTP to changes in inlet characteristics, such as inlet flows, pollution loads and concentrations for various conditions created by an extreme weather event.

The identification of critical locations is very important and helps in the identification of the vulnerability of the system.

Regarding the accuracy of mathematical models, it should be mentioned that the accuracy of model calculations depends on

1) the accuracy of the equations employed in the model to describe the various processes occurring in a sanitation system; thus, the practical knowledge of the specific sewerage system and the WWTP is of great value, and

2) the process of model calibration and verification with real measurements.

Moreover, the accuracy of models in flow conditions corresponding to extreme weather events, i.e. at very high or very low (especially) flow rates decreases, due mainly to the fact that the models have not been calibrated and verified during these conditions.

Mathematical models can be useful mainly for large sanitation systems. However, for small sanitation systems the use of mathematical models is a luxury. In such cases the experience and practical knowledge of the network, as well as of the whole equipment and of its reaction to the past critical events, becomes more important. Thus, the recording of extreme weather events and periodical surveys are of great importance.

5 RISK TREATMENT

5.1 Introduction

Various actions can be taken to treat the risk due to an extreme weather event. In this chapter a series of general actions will be described. These actions have been mainly taken from the following recent documents:

1) U.N.E.C.E. and the World Health Organization Regional Office for Europe. (2009). Meeting of the parties to the protocol on water and health to the convention on the protection and use of transboundary watercourses and international lakes, Guidance on Water Supply and Sanitation in Extreme Weather Events, Draft version June 2009, Second meeting of the task force on extreme weather events. Geneva, October 27-28. Available at: http://www.unece.org/env/water/meetings/documents_TFEWE.htm.

2) N.A.C.W.A. and the Association of Metropolitan Water Agencies. (2009). Confronting climate change: An early analysis of water and wastewater adaptation costs. Available at: http://www.amwa.net/galleries/climate-change/ConfrontingClimate_Change_Oct09.pdf.

More detailed information can be found in the above-mentioned references.

In the process of planning the risk treatment actions for sanitation systems to extreme weather events, the following general points should be taken into account:

1) The actions can be preventive or operational-protective. Preventive actions are taken during the design of the sanitation system or prior to the extreme weather event. These measures must be organized and planned as a part of the standard operation and maintenance of the sanitation system; i.e. they should be linked to the normal (extreme event-free) operation of the system. Protective actions are applied during the occurrence of the extreme weather event; however, these actions should be planned by water managers in advance of the extreme weather event. Specific actions that need to be performed in case a WWTP were to be unavailable due to an extreme event should be clearly described.

2) The actions that are described below are general and should not necessarily apply to all sanitation systems. In other words, the actual measures are site-specific and depend on the characteristics of the specific sanitation system. Therefore, the knowledge of the system (see chapter 4.4) including their vulnerable points will guide towards the decision on the required actions. For example, the vulnerability of a sanitation system is strongly influenced by the number of pumping stations available to pump the excessive water due to a flood back to the receiving water body. Furthermore, WWTPs located on flat land are more vulnerable than those connected to the gravitation sewer. Moreover, WWTPs located on the coast require special attention, because they are endangered by the flooding during the sea storm.

5.2 Actions for risk treatment against floods

The main actions against the impacts due to floods described in chapter 3.2 are as follows:

1) Demand for increased efficiency of WWTPs due to increased pollution of surface waters (IF1).

   The efficiency of specific units and operations of WWTPs should increase. This can be performed more effectively in the design of WWTPs. For example, in activated sludge tanks additional aeration capacity should be ensured (e.g. air blowers of higher capacity) to cope with increased organic loadings and/or increased BOD concentrations together with an efficient control of the process (e.g. via DO concentration sensors). Mathematical models for the design and operation of WWTPs can contribute significantly to cope with this problem.

2) Requirement for higher hydraulic energy of the effluent discharge of WWTPs due to increased water levels of surface waters used for effluent discharge (IF2).

   The pumping efficiency of the outlet works should be increased. Mathematical models for the hydraulic design of WWTPs can be used.

3) Higher velocities, lower retention times and pressure flow due to high flow rates in sewers with a risk for flooding (IF3).

   Additional storm water storage in retention reservoirs and storm water tanks should be provided. Sewerage systems should be designed to cope with expected peak flows. In case of combined sewerage systems, separation between sewer and rain water drainage networks will facilitate the solution of the problem.

4) Reduction of the efficiency of WWTPs due to lower hydraulic retention times (IF4).

   The efficiency of specific units of WWTPs should be increased. This can be performed more effectively in the design of WWTPs.

5) Odor generation in sewers due to heavy loads due to runoff (IF5).

   Additional storm water storage in retention reservoirs and storm water tanks should be provided.

6) Reduction of the efficiency of WWTPs due to increased pollution loadings (IF6).

   The efficiency of specific units of WWTPs should be increased. This can be performed more effectively in the design of WWTPs. WWTPs should be designed to be capable to treat the first flash storm water with high concentration of pollutants.

7) Degradation of sewer conduits due to saline water intrusion (IF7).

   Hardening of sewerage systems to reduce infiltration should be performed. Pipelines should be waterproof and regularly checked.

8) Over-flooding of sewers and units of WWTPs, disruption of the operation and failure of electricity due to storm surges and floods (IF8).

Flood protection measures should be adopted in the phase of the design.

These may include the following:

a. Installation of levees and sea walls around the critical locations of infrastructure of WWTPs, such as pumping stations.

b. Performance of the hydraulic design (hydraulic calculations) of the WWTP in such a way that the critical infrastructure of the WWTP are located at high ground levels, which ensure no-flooding, even for storms of very long return period. Such a solution results in high operation costs due to the higher pumping requirements that are practiced not only during floods, but also during dry periods.

c. Placement of the critical infrastructure of the WWTPs in protective steel containers or concrete structures that ensure the safe operation of the facilities during floods.

5.3 Actions for risk treatment against droughts

The main actions against the impacts due to droughts described in chapter 3.3 are as follows:

1) Demand for increased efficiency of WWTPs due to the decreased dilution capacity and higher concentration of pollutants of surface water bodies used for effluent discharge (ID1).

The efficiency of specific units and operations of WWTPs should increase. This can be performed more effectively in the design of WWTPs. For example, in activated sludge tanks additional aeration capacity should be ensured (e.g. air blowers of higher capacity) to cope with increased organic loadings and/or increased BOD concentrations together with an efficient control of the process, e.g. via DO concentration sensors. Mathematical models for the design and operation of WWTPs can contribute significantly to cope with this problem (see also F1).

2) Partial or full blocking of pipes with a reduction of the hydraulic capacity due to very low flows (ID2).

This consequence can be faced in the design of sewerage system only partially. The application of maintenance programs is expected to face the problem more effectively (see chapter 5.4).

3) Increased population of rodents and undesirable animals in the WWTPs due to very low flows (ID3).

This consequence can be faced in the design of sewerage system and the WWTPs (pipes, channels and units) only partially. The application of maintenance programs is expected to face the problem more effectively (see chapter 5.4).

4) Unpleasant odor from sewers and WWTPs due to very low flows (ID4).

This consequence can be faced in the design of sewerage system and the WWTPs (pipes, channels and units) only partially. The application of maintenance programs is expected to face the problem more effectively (see chapter 5.4).

5) Possible negative effect on the efficiency of WWTPs due to increased concentrations of pollutants, increased hydraulic retention times and modified organic loadings (ID5).

Specific units of the WWTPs should be designed to cope with the expected modified values of all parameters involved, i.e. concentrations, hydraulic retention times, hydraulic and organic loadings. Periodical control and cleaning of electromechanical equipment, pipes and tanks should be carried out.

6) Degradation of sewer conduits due to saline water intrusion (ID6).

Hardening of sewerage systems to reduce infiltration should be performed. Pipelines should be waterproof and regularly checked (see also IF7).

5.4 Maintenance, crisis and emergency programs

5.4.1 Periodical preventive maintenance plans

During floods and droughts the highest possible hydraulic capacity of the existing sanitation systems can be achieved with the periodical preventive maintenance of the components of the sanitation system.

The preventive maintenance of the sanitation system prior to the occurrence of floods or droughts includes:

1) Cleaning of sewers (pipelines and fittings) of the sewerage system and the units of WWTPs to avoid overfilling (see IF3).

2) Keeping the sewers and units of the WWTP waterproof and impermeable to prevent infiltration of wastewater to groundwater as well as not to allow penetration of water from outside to the sewers during floods or droughts (see IF7).

3) Performance of regular control and maintenance of pumping stations. Secure full operability of ordinary as well as emergency electromechanical equipment (flood pumps) of the sanitary system (see IF3).

4) Preparation of alternative electricity sources in case of power failure that may occur during floods. Set in stand by model electric generators (see IF8).

5.4.2 Emergency plans

Maintenance, crisis and emergency plans for sanitation systems for both extreme situations (floods and droughts) should be developed.

Crisis and emergency plans provide operators with management rules and levels of critical indicators; the latter enable them to recognize the potential threat and enable them to respond on time and correctly to the potential emergency situation.

For example, in the case of large sanitation systems, common maintenance and emergency plans for all sectors of the system should be drawn up to secure permanent clearness of the whole system, which involves different operators (probably belonging to different companies) in the different sectors of the system.

The maintenance plan of the sanitation system during the period of floods may include the following:

1) Assessment of the real level of risk. The protection of the WWTP is based on the assessment of the real level of risk, so that:
   a. the operation of the WWTP will be preserved and
   b. flooding of vital equipment (see impact IF8) and pollution of the surface water by washing out of different chemicals prevented (see impact IF1).

2) Use of mathematical models to help in the decision on the operative measures. Mathematical models can be used to define appropriate operative measures during the extreme event in real time (see chapter 4.4). The epicenter of extreme rainfall events is usually confined to a small area; thus, it is possible to use the residual hydraulic capacity of sewer networks by regulating the flow or redistributing storm water towards the less loaded branches (see impacts IF3 and IF8). Such measures require:
   a. inter-connections between the different parts of the sewerage network,
   b. installation and proper maintenance of automatic control system elements within the system, and
   c. a well-calibrated centralized system of real time control (RTC).

3) Central supervision. In large sanitation systems, a central operational unit should be in charge of:
   a. supervising the response of the whole network,
   b. steering special maintenance teams, and
   c. potentially alerting public and other stakeholders involved in the case of risk for public safety, such as sewer back - flooding of urban areas (see impacts IF3 and IF8), possible contamination of sensitive areas with waste water, pollution of water bodies (see impact IF4) and groundwater (see impact IF7), etc.

4) Good communication and cooperation. The operators of large sanitation system should communicate with river authorities, dam and sluices operators, flood protection bodies along the river. Such a communication will enable them to be prepared to immediately install components of the flood mitigation and protection measures, such as mobile flood protection walls, pumping devices etc.

   The operators of small decentralized sanitation systems are not prepared enough to handle emergency situation without help of professionals, mostly because of lack of reserve technology (reserve pumps, tank trucks etc.) and sometimes also because of insufficient expertise of the staff. Good cooperation with the state administration and with operators of central WWTPs or with other organizations owing the necessary equipment during emergency situation can help to overcome this problem.

5) Ensuring full service of WWTPs and pumping stations as long as possible. This can be performed by continual control/maintenance of the:
   a. electro-mechanical facilities, and
   b. the structural compartment of the system.

   Fundamental maintenance activities within the system are:
   a. solid waste disposal, and
   b. cleaning of sewers and the units of WWTPs.

6) Keeping WWTPs in operation as long as possible. During the flood the WWTP should be kept in operation, even if the most of the wastewater is treated only partially. The high dilution capacity of the receiving water body during floods is expected to enable keeping an acceptable quality of water, even if only part of the incoming wastewater (for the characteristics of which the WWTP was designed) is treated completely.

   When flood protection cannot cope with the extremely high flows and the situation does not allow operation of the WWTP anymore (see impact IF8), then it is imperative to remove all equipment, such as pumps and compressors, which are needed for the recovery of the sewerage system and the WWTP (see chapter 5.6). The removed equipment should be safely stored to prevent their damage caused by the flood.

7) Observing basic hygienic requirements. It is very important, especially for small sanitation systems, to prevent the massive escape of dangerous bacteria to surface water (see impact IF8) and groundwater and to keep the sanitary system in operational status as long as feasible, or in the status that can be as quickly as possible recovered to the operational one.

8) Application of practical measures to protect the WWTP and the environment. These measures that can be implemented to face mainly impact IF8 include the following:

   a. construction of flood protection embankment, such as of mobile flood protection walls, around the facilities of the sewerage system and the WWTP`s and sewerage facilities,

   b. closing of anti-backflow devices, such as valves, gates and sluices, and use of pumping stations to protect the sanitation system against the back wave from neighboring flooded water bodies,

   c. removal of all the chemicals and other potentially dangerous contaminants from the area of WWTP and sewer facilities to prevent additional pollution of surface and groundwater,

   d. avoidance of the release of contaminated water and sludge from cesspools and septic tanks, and

   e. protection of drinking water resources, wells and bore wells from contamination by polluted flood water.

The maintenance plan of the sanitation system during the period of long-term drought may include the following:

1) Cleaning of sewers (pipelines and fittings) of the sewerage system to avoid solids accumulation (see impacts ID2, ID3 and ID4).

2) Cleaning of the units of the WWTP; mainly sedimentation and sludge retention tanks, to avoid solids accumulation (see impacts ID3, ID4 and ID5).

3) Cleaning of roads and pavements (urban areas) and sewer system inlets and manholes in the case of large combined sewerage systems (see impacts ID2, ID3, ID4 and ID5).

4) Use of treated wastewater for cleaning; see (1), (2) and (3). Treated wastewater should undergo through additional treatment to satisfy the relevant public health regulations (see impacts ID2, ID3, ID4 and ID5). In this way drinking water is not used and is saved for potable use.

5) Regular control and maintenance of the machine and electric parts of the electromechanical equipment of the sanitation system. Monitoring of the current status of pipelines of the sewerage system and the channels and pipes of the WWTP will identify the areas with possible sediment formation (see impacts ID2, ID3 and ID4) and infiltration (see impact ID6).

6) Regulation of the processes of WWTP to face changes in inlet concentrations and loadings (see impact ID5).

5.4.3 Updating plans

The above-mentioned maintenance and emergency plans should be regularly updated.

5.5 Training programs

5.5.1 Education of staff

The persons who will be involved in the procedure of risk treatment (staff and employees) should have the following characteristics:

1) They should be skilled and capable to recognize the danger (identify the risk), analyze the risk and respond properly.

2) They should be duly educated.

3) They should communicate with each other (e.g. system operators, owners, state administration, river basin authorities, management of official rescue system and all other stakeholders). Moreover, the operators of decentralized sanitation systems should closely cooperate with the state environmental authorities and with operators of the main centralized sanitation systems to use the experience and equipment of these organizations. It is advisable to sign agreements on cooperation in these emergency situations.

5.5.2 Information of managers regarding environmental information

Water managers (of mainly large sanitation systems) should have:

1) knowledge of weather change indicators,

2) provision of information on current weather conditions in their areas, and

3) knowledge of hydrological regime of adjacent surface water bodies.

The above-mentioned knowledge enables them to respond appropriately to the local “extreme weather” climate changes (such as increased rains or decreased periods between flash rains) and to prevent overloading and engorgement of their sanitary systems

5.6 Recovery of the wastewater treatment plant after the flood event

The restoration of the operation of a WWTP after flood has to be performed immediately after the event. The following procedure can be applied (UNECE, 2009):

1) General primary measures:
   a. making the area of the WWTP accessible,
   b. documenting the damage,

c. gradual removal of dirt,
d. performance of disinfection and cleaning of buildings and equipment,
e. assessment of the structural and operational capability of buildings and equipment, and
f. drawing up of a plan for the restarting procedure of the WWTP operation.

2) Technological measures:
a. ensuring electrical energy supply, and
b. making the sewerage network and WWTP accessible.

3) Putting the WWTP into operation. The start of the operation of a WWTP after flood is a gradual procedure as follows:
a. manual start of the stage of preliminary treatment (screens, grit chamber and grease removal) and disinfection (e.g. chlorination) and by-pass of the rest stages,
b. manual start of the sludge treatment units, at least the sludge storage tanks (including thickeners, digesters), to be able to receive the produced sludge,
c. manual start of the stage of primary treatment (including primary settling tanks and chemical precipitation),
d. manual start of the stage of secondary-biological treatment that includes the biological reactors, such as selectors, biological removal phosphorus tanks, anoxic tanks, aeration tanks and MBR tanks) and secondary settling tanks,
e. manual start of the stage of additional treatment for effluent reuse, and
f. start of the automated operation system.

The most difficult part of this gradual procedure is (d); i.e. to put the biological treatment stage into operation. During the flood, activated sludge is usually washed away from the tanks, or the sludge is in the process of decay. The problem can be solved by one of the following methods:

1) inoculation with sludge from another WWTP,

2) "cultivating" of new active sludge without inoculation, or

3) using the original sludge, although decayed, that has not been washed and is kept in the secondary settling tanks.

6 CONCLUSIONS

In the present report:

1) the main aspects and impacts-consequences of floods and droughts on sanitation systems, which consist of the sewerage system and the Wastewater Treatment Plant (WWTP), are described, and

2) the main actions for the treatment of risk of these impacts are presented. These actions are general and should not necessarily apply to all sanitation systems. In other words, the actual measures are site - specific and depend on the characteristics of the specific sanitation system.

The information contained in this report:

1) is based on a series of references that are reported in the list of references and in the main chapters of the report, and

2) can be used for the formulation of a Contingency Plan for a specific sewerage system.

LIST OF REFERENCES

1) Baum, R.L., Savage, W.Z. and Godt, J.W. (2002). TRIGRS — A fortran program for transient rainfall infiltration and grid-based regional slope-stability analysis. U.S. Geological Survey Open-File Report 02-0424.

2) Giannakopoulos, C., Bindi, M., Moriondo, M., Lesager, P. and Tin, T. (2005). Climate change impacts in the Mediterranean resulting from a 2˚C global temperature rise. WWF Report, Gland, Switzerland, WWF.

3) IPCC (2007). Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

4) IPCC (2001). Climate Change 2001: The Scientific Basis. Contribution of WG1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

5) Schijven, J. and Husman A. M. De Roda (2005). A Survey of Diving Behaviour and Accidental Water Ingestion among Dutch Occupational and Sport Divers to Assess the Risk of Infection with Waterborne Pathogenic Micro organisms, Environmental Health Perspectives (Available at: http://ehp03.niehs.nih.gov/article/fetchArticle.action?articleURI=info%3Adoi%2F10.1289%2Fehp.8523).

6) DSP (2004). Sewage Treatment Divisions One & Two, Drainage Services Department, Contingency plan for incidents possibly encountered in sewage treatment facilities having a potential of generating an environmental nuisance. Available at: http://www.epd.gov.hk/eia/register/ report/eiareport/eia_0972004/pdf/eia2/app4.5. pdf.

7) Euripidou E, and Murray V. (2004). Public health impacts of floods and chemical contamination, J Public Health (Oxf), 26(4), 376-83 (Available at: http://www.ncbi.nlm.nih.gov/pubmed/15598858).

8) NACWA (2009). N.A.C.W.A. and the Association of Metropolitan Water Agencies, Confronting climate change: An early analysis of water and wastewater adaptation costs. Available at: http://www.amwa.net/ galleries/climate-change/ ConfrontingClimateChangeOct09.pdf.

9) SAEPA (2009). South Australian E.P.A. Guidelines, Contingency plans- a guide for wastewater producers and wastewater treatment plant operators. Available at: http://www.epa.sa.gov.au/xstd_files/Waste/ Guideline/ guide_contingency.pdf.

10) UNECE (2009). U.N.E.C.E. and the World Health Organization Regional Office for Europe, Meeting of the parties to the protocol on water and health to the convention on the protection and use of transboundary watercourses and international lakes, Guidance on Water Supply and Sanitation in Extreme Weather Events, Draft version June 2009, Second meeting of the task force on extreme weather events. Geneva, October 27-28. Available at: http://www.unece.org/env/water/meetings/ documents_TFEWE.htm.

11) http://www.minenv.gr/medeuwi/download/Theme_2_Climate&Water_%20150708.pdf.

12) http://www.greenpeace.org/.

13) http://sedac.ciesin.columbia.edu/ddc/sres.

14) http://www.who.int/globalchange/publications/climatechangechap6.pdf.

15) http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240549/pdf/ehp109s-000141.pdf.

16) http://www.springerlink.com/content/l618677705577364/fulltext.pdf.

17) http://www.planbleu.org/publications/changement_clim_energie_med_EN.pdf.

18) http://pentes-tunnels.eu/enseignement/cours_RMF_2A/papier_xian/013.pdf.

19) http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1370852.

20) http://assets.panda.org/downloads/wwf_drought_med_report_2006.pdf.

21) http://www.greenpeace.org/international/Global/international/planet-2/report/2006/3/climate-change-and-the-mediter.pdf.

22) http://archive.greenpeace.org/climate/science/reports/fulldesert.html.

23) http://www.floodsite.net/html/faq2.htm.

24) http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch8s8-2-2.html.