Journal of Polish Safety and Reliability Association
Summer Safety and Reliability Seminars, Volume 7, Number 1, 2016

Kołowrocki Krzysztof

Soszyńska-Budny Joanna

Torbicki Mateusz
Gdynia Maritime University, Gdynia, Poland

Identification of climate related hazards at the Baltic Sea area and their critical / extreme event parameters' exposure for port oil piping transportation critical infrastructure

Keywords

climate hazards, extreme event parameters, port oil piping transportation critical infrastructure

Abstract

This article aims to identification of the climate related hazards at the Baltic Sea area and analysis the port oil piping transportation critical infrastructure exposure to their extreme event parameters. There are distinguished possible natural hazards coming from the climate-weather change which have influence on this critical infrastructure: strong winds, high and low sea water level, precipitation, large waves, fire, water, soil and air temperature. The potential hazards' parameters with their range and scale are described for the port oil piping transportation system operating at under sea waters in Gdynia Port and at land in the Dębogórze Terminal. Moreover, the impact and consequences of the influence of the extreme parameters on the components of the considered critical infrastructure are analyzed as well.

1. Introduction

Critical infrastructures are very susceptible to the impact of natural hazards. Most of them are related to the climate-weather change. This article is created to identification of possible climate related hazards which appear in the Baltic Sea area and have an impact on the port oil piping transportation critical infrastructure (POPTCI). There are also described the critical/extreme states of the climate-weather hazard parameters, their impact on the considered critical infrastructure and the consequences of operating of the critical infrastructure in those extreme states.

We consider the following hazard parameters and consequences affected by them: strong winds, sea water level, precipitation of rain and snow, large waves, water, air and solid temperature (the description of these hazards affecting critical infrastructures at the Baltic Sea area may be found in [9]), fire, when the POPTCI is operating at under sea waters and at land in Dębiogórze Terminal. This consideration is also discussed in [4].

2. Identification of climate related hazards, their impacts and consequences for POPTCI

The POPTCI transports oil between the pier of Gdynia Port (Polish Baltic seaside) and Oil Terminal in Dębogórze (near Polish Baltic seaside). This terminal is composed of four parts „*A*", „*B*" and „*C*", linked by the Port Oil Piping Transportation System (POPTS) with the pier placed in Port of Gdynia (the breakwater station called Fuel Reloading Post), and a post „*PB*". This critical infrastructure is described in [2] and [3].

The POPTS is denoted by S and composed of three subsystems S_1, S_2, S_3. It is shown in *Figure 1* and *2*. Moreover, in these figures are also illustrated points in which obtained the climate-weather data describing the climate-weather change process for the POPTS operating at under sea water and at land Baltic seaside area. These data are used in [7]-[8].

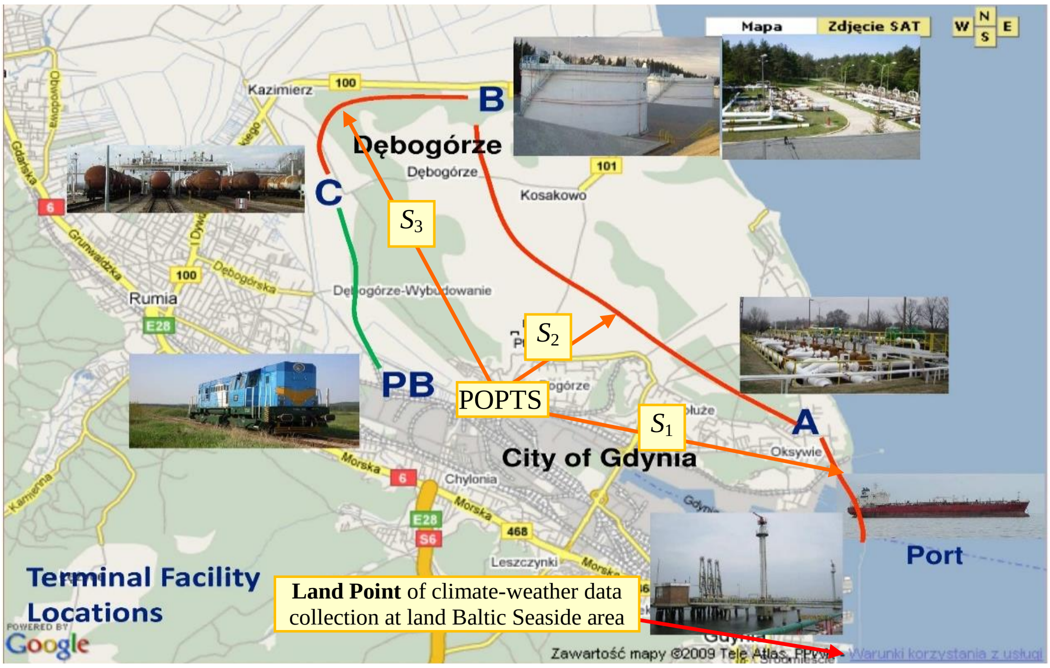

Figure 1. The POPTS operating between Port of Gdynia and Terminal in Dębogórze

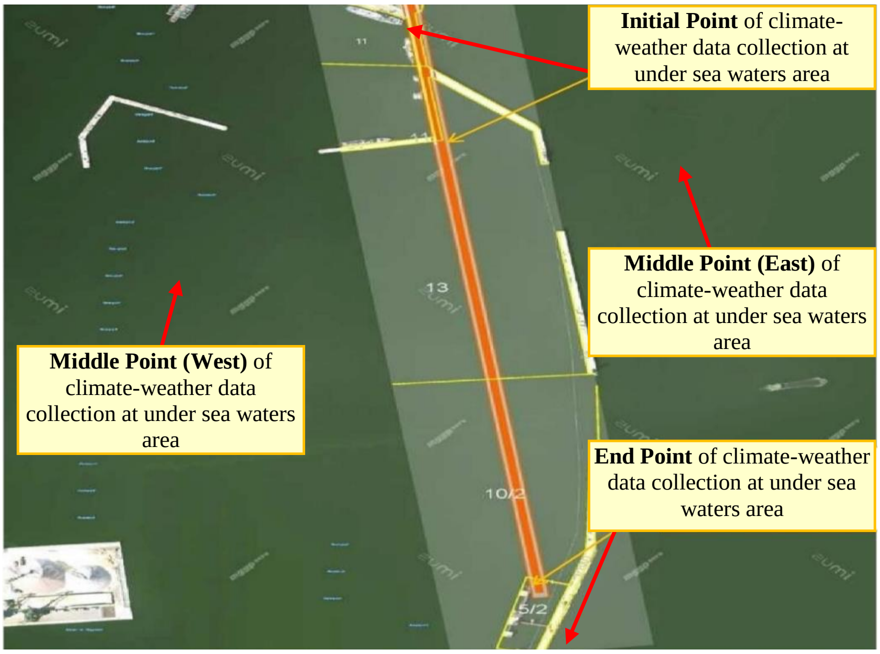

Figure 2. The POPTS operating in Port of Gdynia

In next subsections, the impact of different environmental conditions on the considered POPTS and influences of the climate-weather hazards on this system and their consequences are considered in the following two areas [3]:

- POPTS operating at under sea waters in Gdynia Port,
- POPTS operating at land in Dębogórze Terminal.

The possible intervals contained the values of the considered hazard parameters for described areas are distinguished based on the data about ranges of hazard parameters in [4] and [5].

2.1. Climate-Weather Hazards for POPTS operating at under sea waters in Gdynia Port

On the basis of data from [4] and [5], the possible hazard parameters values intervals for the POPTS operating at under sea waters in Gdynia Port are shown in *Table 1*. They represent the scale of the climate-weather hazards impact on the POPTS operating at considered areas .

Table 1. Hazard parameters impact matrix for the POPTS operating at under sea waters in Gdynia Port

Hazard parameter	Range / state								
Wind speed [m/s]	0 – 5	5 – 11	11 – 17	17 – 33					
Wind direction [azimuth degrees °]	0 – 11.25, 337.5 - 360 N	11.25 – 33.75 NNE	33.75 – 67.5 NE	67.5 – 112.5 E	112.5 – 157.5 SE	157.5 – 202.5 S	202.5 – 247.5 SW	247.5 – 292.5 W	292.5 – 337.5 NW
Sea water level [cm]	415 – 450	450 – 470	470 – 490	490 – 510	510 – 530	530 – 550	550 – 620		
Wave height [m]	0 – 2	2 – 3	3 – 5	5 – 14					
Sea water temperature [°C]	-1 – 3	3 – 6.5	6.5 – 10	10 – 13	13 – 16.5	16.5 – 20	20 – 27.5		
Air temperature [°C]	-30 – -10	-10 – -2	-2 – 6	6 – 14	14 – 22	22 – 30	30 – 40		

- low impact
- medium impact
- high impact
- extreme state

The influence of the individual hazard parameters on the POPTS operating at under sea waters in Gdynia Port may bring the dangerous consequences which are described below [4].

a) Wind speed

If the system operates when the winds speed is above 17 m/s then may appear the mechanical damage involving the rupture of a pipeline at the weld at the joint section or the damage of the insulation of the pipeline. The reason of those damages are waves which are done by the wind. They affects on the part of a pipeline in the transition zone in above-water/underwater part.

b) Wind direction

The wind from extreme directions may cause the deviation from the axis pipeline, the resonance and increased tension of the pipeline. The least favorable wind direction is the wind from the northeast (NE) which results in a growing wave within the basin of the port. This results in wave occurrence, which affects the part of a pipeline in the transition zone in above-water/underwater part. The part of a pipeline located right below the water surface is not exposed to the wind.

c) Sea water level

The water level does not affect the installation of the pipeline. However, the low water level (from 415 cm up to 450 cm) in the harbor basin may limit the size of ships entering the unloading or loading.

d) Sea water temperature

If the system operate in the first extreme state (when the sea water temperature is from -1 °C up to 3 °C) there may emerge ice and its movement could cause mechanical damage to the pipeline. Moreover, during loading or unloading tanker, pressing of the product having a high temperature (eg. the product directly from the production) at extremely low water temperatures cause rapid changes in the steel linear expansion, of which the pipeline is made, that could result in damage to the pipeline within the welds.

If the system operate in the second extreme state (when the sea water temperature is from 20.0 °C up to 27.5 °C) there may appear the damage to the pipe fittings and gaping the pipeline installation due to an increase in pressure (especially on surface areas exposed to external factors).

e) Air temperature

If the system operates when the air temperature is from -30 °C up to -10 °C then could appear the same consequences as in the case when the sea water temperature is in its first extreme state (from -1 °C up to 3 °C). If the air temperature is in the second extreme state (when the air temperature is from 30.0 °C up to 40 °C) then during loading or unloading tanker, pressing of the product having a low temperature at extremely high air temperatures cause rapid changes in the steel linear expansion, of which the pipeline is made, which could result in damage to the pipeline within the welds. Heating the product inside the pipeline could result in an increase of its volume and an increase in pressure that may cause damage to the pipe fittings and gaping pipeline installation.

Table 2. Hazard parameters impact matrix for the POPTS operating at land in Dębogórze Terminal

Hazard parameter	**Range / state**						
Snowfall level [cm/h]	0 – 10	10 – 20	20 – 30	30 – 60			
Wildfire level							
Rainfall level [mm/h]	0 – 15	15 – 30	30 – 50	50 – 85			
Air temperature [°C]	-25 – -15	-15 – -7	-7 – 1	1 – 9	9 – 17	17 – 25	25 – 35
Soil temperature [°C]	-30 – -5	-5 – 0	0 – 5	5 – 10	10 – 15	15 – 20	20 – 37

- unmeasurable impact
- low impact
- medium impact
- high impact
- extreme state

2.2. Climate-Weather Hazards for POPTS operating at land in Dębogórze Terminal

On the basis of data from [4] and [5], the possible hazard parameters values intervals for the POPTS operating at land in Dębogórze Terminal are shown in *Table 2*.
They represent the scale of climate-weather hazards impact on the POPTS operating at considered areas.
The influence of the individual hazard parameters on the POPTS operating at land in Dębogórze Terminal may bring the dangerous consequences which are described below [4].

a) Wildfire level

The appearance of fire could cause damage to the pipe fittings and gaping the pipeline installation due to an increase in pressure (increasing product pressure is caused by a sudden increase in soil temperature in the area). Moreover, it may make explosion and ignition of the product leaking from the installation.

b) Air and soil temperature

If the system operates in very high or low temperatures of the air or solid then the differences between the product temperature and the extreme temperatures of air and soil may cause rapid changes in the steel linear expansion, of which the pipeline is made, which could result in damage to the pipeline within the welds. Moreover, heating the product inside the pipeline could result in an increase of its volume and an increase in pressure that may cause damage to the pipe fittings and gaping the pipeline installation.

2.3. Resilience strengthening strategy to climate-weather hazards for POPTS

The resilience strengthening strategy to climate-weather hazards for the POPTS operating at under sea waters in Gdynia Port and at land in Dębogórze Terminal is described in [4]. According to the primary answers of our consultants (stakeholders) from industry, there are distinguished the following resilience strategies for the particular hazards affecting the POPTS:

– identifying the most critical components;
– testing of pipelines using advanced non-destructive testing (NDT) techniques;
– testing the tightness of the insulating coating of the pipeline;
– testing of mechanical properties of pipelines, i.e. tensile strength and ductility;
– inspections of all welds (for example detecting defects by applying long range ultrasonic testing (LRUT) to pipes in order to anticipate future problems and extend the pipeline's lifetime);
– construction of the breakwater in areas exposed to wind in the transition zone;
– repair or replacement of sections and pipeline components and/or serving pipe fittings;
– placing the pipeline in the casing pipe in the transition zone between above water and underwater sections (the optimal solution would be to lead the whole underwater section of the pipeline in a protective tube and protection of the above water pipeline's section to the entry ashore);
– anchor strengthening of the horizontal section of the underwater pipeline routed along the bottom of the dock;

– strengthen the lattice construction, which are located in the transition zone between above water and underwater part of the pipeline and are responsible for strengthening the pipeline protection structure and ensure proper connection of the pipeline to the mainland;
– to reinforce the coastline to protect the pipeline from the impact of the strake wave and sea erosion;
– applying pressure monitoring systems, along with regulators and pressure reducers;
– installing the pressure sensors that indicate a possible leak in the pipeline;
– including emergency shutoff valves along the pipes to ensure proper medium pressure in the distribution network;
– cooling/heating of the product (medium) before distribution to the pipeline;
– preparation of a contingency plan in the event of a leak;
– the availability of appropriate resources and efforts to reduce the negative effects of the spill material;
– building of the expansion installation at the cut section of the pipeline (three sections i.e. the section between SPPP and a gate valve, the section between a gate valve and the part „*A*" and between the part "A" and the part "B");
– using appropriate fire alarm and fire protection systems;
– installation of reservoirs spoilers fire.

3. Conclusions

In this article are identified possible climate related hazards which have an influence on the POPTS. The extreme states of the climate-weather hazard parameters, their impact on the considered critical infrastructure and the consequences of operating of the POPTCI in those extreme states are described. They are very dangerous but if the strategy of strengthening the resilience to climate-weather hazards for POPTCI fixed in subsection 2.3 is used then the risk of appearing the damage will be low.
Moreover, the possible hazard parameters values intervals for the POPTS showed in *Table 1* and *2* are used in [6].

Acknowledgments

The paper presents the results developed in the scope of the EU-CIRCLE project titled "A pan – European framework for strengthening Critical Infrastructure resilience to climate change" that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653824. http://www.eu-circle.eu/.

References

[1] Blokus-Roszkowska, A., Bogalecka, M. & Kołowrocki, K. (2016). Critical infrastructure networks at Baltic Sea and its seaside. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 7-14.
[2] Drzazga, M., Kołowrocki, K., Soszynska, J. et al. (2016). Port oil piping transportation critical infrastructure assets and interconnections. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 1, 37-42.
[3] EU-CIRCLE Report D1.2-GMU1. (2016). *Identification of existing critical infrastructures at the Baltic Sea area and its seaside, their scopes, parameters and accidents in terms of climate change impacts*.
[4] EU-CIRCLE Report D1.3-GMU4. (2015). *Contributions to generating Questionnaire of End User Needs*.
[5] EU-CIRCLE Report D2.1-GMU3. (2016). *Modeling Climate-Weather Change Process Including Extreme Weather Hazards*.
[6] Jakusik, E., Kołowrocki, K., Kuligowska, E. et al. (2016). Modelling climate-weather change process including extreme weather hazards for port oil piping transportation system, *Journal of Polish Safety and Reliability Association Summer Safety and Reliability Seminars* 7, 3.
[7] Jakusik, E., Kołowrocki, K., Kuligowska, E. et al. (2016). Identification methods and procedures of climate-weather change process including extreme weather hazards for port oil piping transportation system operating at land Baltic seaside area. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 3.
[8] Jakusik, E., Kołowrocki, K., Kuligowska, E. et al. (2016). Identification methods and procedures of climate-weather change process including extreme weather hazards for port oil piping transportation system operating at under water Baltic Sea area. *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 3.
[9] Kuligowska, E., Kołowrocki, K. & Soszyńska-Budny, J. (2016). Climate related hazards and their critical / extreme event parameters exposure for maritime ferry critical infrastructure, *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 1, 111-118.
[10] Kolowrocki, K. & Soszynska-Budny, J. (2011). *Reliability and Safety of Complex Technical Systems and Processes: Modeling-Identification-*

Prediction-Optimization. Springer, ISBN: 9780857296931.