Project WISA

STORMWATER SAMPLING STRATEGY IN SEAPORT AREAS

INTRODUCTION

HELCOM has identified several earlier unknown major point sources of nutrient pollution in the Baltic Sea Region countries related to the production of phosphate and nitrogen fertilizers. All of those sites required pollution mitigation measures to be taken urgently. Based on these findings, organizations within the Coalition Clean Baltic (CCB) network have raised attention to the need of evaluating the whole fertilizer production/logistics chain.

Most dry bulk commodities are prone to spillage and dust pollution, posing environmental problems even for ports, which handle comparatively low tonnages. Ports which handle bulk materials – either incoming, outgoing or both – are confronted with critical ship-to shore transfer problems, which are far more complex than those involving ship loading or unloading of general cargo or containers. The dry bulk cargo also needs to be stored, if only temporarily, within the port zone. It also needs to be conveyed between the quayside and the storage location. A major environmental problem, common to these operations and unique to dry bulk cargo handling, is that of material spillage and dust pollution. Storage, if uncovered, adds to complications in the event of stormwater runoff[1].

Port stormwater is derived from precipitation and runoff that comes in contact with port various cargo storage, loading, ship manufacturing, repair, freight transport vehicles, other activities and then runs offsite and enters drainage systems or receiving waters. Several factors such as weather conditions, drainage area characteristics and the nature of activity affect the runoff and pollutants contribution from port areas. Sampling stormwater discharges can help to identify the source of pollutants as well as pollution loads, entering the receiving waterbodies. Though, stormwater sampling may be complicated due to dynamic characteristics of stormwater flow, the diffuse nature of many stormwater flows, many potential pollutants and pollutant characteristics that may washed-off from impervious port area surfaces.

[1] CCB Report - Concept Best Available Technologies & Techniques: Bulk Fertilizer Handling. Uppsala, Sweden, 2019

One of the major concerns regarding stormwater runoff is the direct contribution of nutrients and sediments into receiving water bodies. The main project WISA purpose is to determine drainage sub-basins in the ports areas, investigate the level of stormwater control in each sub-basin and determine high priority areas for advanced stormwater management opportunities. The objectives for WP3 are as follows:

- Identify existing stormwater infrastructure through port engineering drawings, pollution permit documentations, other relevant sources of information,
- determine runoff volumes and contaminant loadings from ports drainage areas, with focus on bulk fertilizer loading terminals;
- based on literature review and applicable practices in ports, develop the water quality monitoring framework for priority runoff areas.

CURRENT DOCUMENT AIMS TO ANSWER THE FOLLOWING QUESTIONS:

- What kind of rain events can be identified and how do they affect stormwater quality in port areas?
- How many measurable storm events should be sampled, how many samples should be collected per storm event to make statistically accurate estimates, should stormwater runoff be sampled manually (i.e., grab), or automatically, etc.

1. STORMWATER SAMPLING EXPERIENCE IN PARTNER'S SEAPORTS

WISA project study areas include three seaports: Klaipėda port in Lithuania, Gdynia port in Poland and Åhus port in Sweden. In all the studied ports stormwater is drained with separate underground sewer system/pipes that collect the drainage area runoff and, depending on local conditions and requirements, discharge untreated or treated on-site local treatment plants to nearby water bodies.

A comparative analysis of stormwater handling practices from partner's countries summarized below.

1.1 STORMWATER MANAGEMENT LEGISLATION

LITHUANIA

According to Lithuanian legislation, data on stormwater management must be recorded by the economic entities/operators, as well as Klaipeda port companies, discharging stormwater into the surface water bodies and have an IPPC (**Integrated Pollution Prevention and Control Permit**) or **Pollution Permit** (simplified version of IPPC permit). Stormwater management data includes this basic information: measured stormwater runoff concentrations, calculated annual runoff volumes and pollution loads, including treatment plants hydraulic capacity and outfalls/outlets coordinates. Stormwater quantitative and qualitative data are based on discrete sample-grab sampling at one time self-monitoring results. This means that only grab sampling is required.

All this and additional information shall be submitted by the individual port companies to the LT Environmental Protection Agency (EPA) annually. The EPA reviews, processes the received data and stores annual statistics of all companies in a database.

THE DATA PROCESSED BY THE EPA PROVIDE THESE ANNUAL FIGURES AND INFORMATION:

- sampling point coordinates,
- stormwater volume, thous m^3/a;
- average annual concentration;
- highest actual concentration;
- pollution load, kg/a;
- average annual allowable concentration of permitted parameters/ substances.

Wastewater/stormwater operators must monitor the effluent discharged to receiving water bodies. The aim of the self-monitoring is to assess whether the pollution amounts/indicators discharged from pollution sources do not exceed the established limits and/or standards. Stormwater samples are taken and tested by private contract accredited or authorised laboratories.

EPA also implement compliance monitoring programs and pursue enforcement is provided through local environmental inspectors. Compliance monitoring procedures necessary to determine compliance and non-compliance with permit conditions.

Some parameters specific to stormwater and their permissible concentrations are demonstrated in the table 1 and general requirements in table 2 below. COD values not determined.

TABLE 1. ALLOWABLE CONCENTRATIONS IN STORMWATER DISCHARGES TO RECEIVING WATERBODIES, MG/L

	Endorsed by Stormwater Management Regulations				Endorsed by Wastewater Management Regulation[2]								
	Suspended solids	BOD_7[1]	BOD_7	Oil products	N_{total}	P_{total}	Zn	Pb	Cd	Cu	Hg	As	Cr
Maximum allowable concentration	50	34	10	7	-	-	-	-	-	-	-	-	-
Average annual concentration	30	23	-	5	30	4	0,4	0,1	0,04	0,5	0,002	0,05	0,5

[1] BOD parameter must be specified and monitored in stormwater effluents contaminated with organic substances (e.g. agricultural processing, food industry, organic waste management facilities, etc.). In other cases, the maximum allowable concentration of BOD_7 is 10 mg O_2 / l, the average annual concentration is not determined.

[2] N_{total}, P_{total}, Zn, Pb, other hazardous and priority substances discharged into surface water bodies shall not exceed average annual concentration specified in the Wastewater Management Regulation approved by the LT Minister of Environment 17 May 2006.

TABLE 2. GENERAL REQUIREMENTS FOR DISCHARGES INTO THE NATURAL ENVIRONMENT

Parameter	Unit of measurement	Limit value[3]
Maximum temperature	°C	not exceeding 30[1]
pH[2]	-	6,5-8,5
Mineralization	g/l	not more than 2

[1] unless otherwise provided by other legislation.

[2] Should be monitored for a longer period of time, eg 14 days. Instantaneous pH values of 4 ÷ 6.4 and 8.4 ÷ 10 are permissible if their duration does not exceed 6 minutes in one hour. (10% of the time).

[3] unless otherwise provided by other legislation.

POLAND

The Act of July 20, 2017, states that the institution will install devices for measuring the amount of stormwater and melt water by the end of 2020 (to be installed by Polish Water State Authority 'Wody Polskie'). Currently, Port of Gdynia collects and registers data based on its calculations, which are submitted to the Polish Water State Authority 'Wody Polskie'. Port of Gdynia downloads appropriate statements/reporting form? from 'Wody Polskie' website, fills them and sends back. Port of Gdynia calculates the load itself (based on the amount of water drained).

Data on the amount of stormwater that can be discharged through the stormwater drainage system into the receiving water body are regulated by a **Water Law permit** issued by the 'Wody Polskie'. Water Law permit specifies following obligatory parameters to be controlled in the stormwater:

- total suspended solids (TSS) (maximum allowable concentration ≤ 1000 mg/l)
- petroleum hydrocarbon contamination (maximum allowable concentration ≤ 15 mg/l)

The Regulation of the Minister of the Environment of November 18, 2014 specifies the conditions that must be met when dealing with the wastewater. There are more hazardous substances included in the regulation for draining sewage into the soil, but the Port of Gdynia is only subject to a Water Law permit, providing maximum allowable concentrations (MAC) for total suspended solids and petroleum hydrocarbons. This is the reason why Port of Gdynia is responsible for measuring only these two substances for already 30 years.

Chemical analysis carried out by an accredited laboratory within the meaning of the provisions of the Act of 30 August 2002 on the conformity assessment system.

The port in Gdynia is not obliged to provide collected stormwater data to any agencies. Usually, if the 'Wody Polskie' gives a document with data to the owner of the water device (e.g. outlet), he generally has it for himself and uses it if necessary.

Environmental enforcement institutions don't carry out compliance monitoring, neither sampling nor any analysis.

Only relevant environmental bodies can obtain stormwater data from Port of Gdynia, but not other interested people.

SWEDEN

In Sweden there is no legislation regulating stormwater management/sampling procedures. According to the environmental laws in Sweden, the company is obliged to ensure that the activity has no or limited environmental effect.

During the recent years there has been an increasing focus on diffuse pollutants, such as stormwater, by the Swedish authorities. In the company's authorization the stormwater can be one of the issues to control. It's the County board, which set the limit values for pollutants. These values could either be as allowable concentration or an annual amount. The value will vary depending on how sensitive the recipient is.

So far, there are no requirements for stormwater management / discharges into water bodies as well as no limit values for pollutants are set for the Åhus port, which is being investigated by the environmental authorities.

1.2 STORMWATER SAMPLING TYPE AND FREQUENCY

LITHUANIA

IPPC or Pollution permits, among other conditions set stormwater monitoring parameters and sampling frequency. Normally, operators must take grab stormwater effluent samples four time per year (once per quarter) during the storm event. Samples should be taken not earlier than 15 minutes after the rainfall begins. Only one grab sampling is required.

There are two methods that can be used to determine the volume of runoff: actual annual run-off (W_f) volume measured with measuring devices or, in their absence, calculated using the formula[2]:

$$\mathbf{W_f = 10 \times H_f \times p_s \times F \times K,\ m^3\ /\ year}$$

WHERE:

H_f - actual annual rainfall (mm) (according to the Lithuanian Hydrometeorological Service data);

p_s - runoff coefficient reflects the surface characteristics (various pervious and impervious surfaces) of the contributing runoff basin. The range of runoff coefficient values varies from 0.2 to 0.85:

Ps 0.85 – roof coverings;

Ps 0.83 – waterproof coverings;

Ps 0.78 – stone pavement;

Ps 0.4 – partially watertight surfaces (eg. compacted soil, gravel, crushed stone, etc.);

Ps 0.2 – green areas (meadows, lawns, flower beds, etc.) with water collection infrastructure;

Ps 0.8 – when the area is planned and / or the surface type is not known.

F - runoff basin area (ha);

K coefficient reflects snow removal from the drainage basin. If snow is removed, K = 0.85 if not removed (K = 1).

All Klaipeda port companies use above formula for the calculation of the annual runoff volume.

POLAND

Stormwater monitoring program is regulated by the Regulation of the Minister of the Environment of November 18, 2014 on the conditions to be fulfilled when discharging

[2] Stormwater Management Regulations approved by LT Minister of Environment 2 April 2007 consolidated version from 11/01/2019.

sewage into waters or into the ground, and on substances that are particularly harmful to the aquatic environment. Regulation conditions does not cover sampling techniques.

Stormwater or snowmelt entering the waters or into the ground from purification devices is tested when the nominal capacity is greater than 300 l / s and it is assessed on the basis of inspections and on the basis of tests: in the scope of standardized pollution indicators made during rainfall, at least twice a year, in spring and autumn; the test sample is obtained by mixing three samples of equal volume taken at intervals of not less than 30 minutes.

Stormwater samples are taken manually by a company worker who takes water from the stormwater manhole. The sampling frequency is determined by accredited laboratory, which is selected by port authority. The volume of runoff is calculated using the formula:

$$Q = \psi \cdot I \cdot A$$

WHERE:

ψ - run-off coefficient;

I - intensity of rain [dm^3/s ha] – data from Meteorology Institute

A - catchment area [ha]

RUN-OFF COEFFICIENT VALUES:

Roof slope above 15% – 0

Roof slope below 15% – 0.8

Concrete surface – 0.9

Garden – 0

Sidewalk – 0

SWEDEN

To keep it simple to handle, Port of Åhus is using **automatic time-weighted sampling.** A sample analysis covers one hour and consist of four pooled subsamples, one sample taken every 15 min. Sample size 120 – 240 ml depending on bucket size. Sampling starts at chosen time by following the weather forecast (via an electronic rain gauge, it is possible to follow exactly the amount and occasion of the precipitation); the target is to start samples before rain starts to ensure first flush. When started it runs for 24 hours, so normally it covers the entire storm event.

Via the rain gauge it is possible to see hourly (in fact every 5min) how much it has rained during each separate sample. With this information is it possible to make a pooled sample with the same proportions as the precipitation by hour. If the precipitation varies a lot during the storm event it might be a good idea to mix the sample in proportionally.

After the analysis of stormwater samples (either separate or composite) total pollution load (as well as hourly load) of the storm event can be estimated (concentration x amount of water). The volume of runoff is calculated using the formula:

Area x precipitation x runoff coefficient

AS A BASIS, FOLLOWING VALUES OF RUNOFF COEFFICIENT CAN BE USED:

Roof – 0.9

Asphalt / concrete area – 0.8

Stone pavement – 0.7

Gravel road – 0.4

Gravel area not compacted – 0.2

Green area – 0.1

2. STORMWATER MANAGEMENT EXPERIENCES FROM OTHER COUNTRIES

2.1 STORMWATER MANAGEMENT APPROACHES

The purpose of this section was to develop and understand current strategies used in stormwater sampling and management in other countries. This was done by literature review. Mostly electronic search was conducted. The search resulted that many academic articles are related to stormwater management through application of various control measures, modelling tools, etc. The most recent comprehensive publications and detailed recommendations for wider application of the best stormwater management practices was published in the USA. Specifically, the following two provided below references developed by EPA and Washington State Department of Ecology were utilized. They are not official documents but can be used for the purpose of WISA project.

Current EPA's 2015 Multi-Sector General Permit (MSGP) for Stormwater Discharges Associated with Industrial Activity, Section 6.1.3 of 2015 MSGP states that for all required monitoring[3]:

- The monitoring must be performed during a measurable storm event that results in an actual discharge of stormwater from a site that follows the preceding measurable storm event by at least 72 hours (3 days), unless it is proved by permittee that less than a 72-hour interval is representative for local storm events during the sampling period. Measurable amount of rainfall must be greater than 0.1 inch (2, 54 cm).
- In the case of snowmelt, monitoring must be performed at a time when a measurable discharge occurs at the site.
- Each monitoring event, except snowmelt monitoring, must identify:
    - The date and duration (in hours) of the rainfall event,
    - Rainfall total (in inches) for that rainfall event, and

[3]https://www.epa.gov/sites/production/files/2015-10/documents/msgp2015_finalpermit.pdf

    - Time (in days) since the previous measurable storm event

- For snowmelt monitoring must be identified the date of the sampling event
- Minimum of one grab sample from a discharge resulting from a measurable storm event, samples must be collected within the first 30 minutes of a discharge (runoff starts) associated with a measurable storm event;
- Monitoring is required on a quarterly basis (e.g., benchmark monitoring) or once per year (depending on the type of monitoring). EPA may determine additional parameters to be monitored;
- In some case where stormwater is discharged to impaired waters, monitoring should cover all pollutants for which the waterbody is impaired.

Monitoring requirements apply to each authorized outfall with exemption from monitoring for "substantially identical outfall." *If your facility has two or more outfalls that you believe discharge substantially identical effluents, based on the similarities of the general industrial activities and control measures, exposed materials that may significantly contribute pollutants to stormwater, and runoff coefficients of their drainage areas, you may monitor the effluent of just one of the outfalls and report that the results also apply to the substantially identical outfall(s).*

In 2017, a committee was created by the National Academies of Sciences, Engineering, and Medicine through support by the Environmental Protection Agency to address several concerns related to the stormwater monitoring in the Multi-Sector General Permit (MSGP). The committee 2019 report, **Improving the EPA Multi-Sector General Permit for Industrial Stormwater Discharges**[4], recommends several ways that EPA can strengthen the MSGP program to provide its intended environmental protection while balancing the overall burden of monitoring on industry.

The MSGP is one of three permit programs under the Clean Water Act – the other two govern municipalities and construction sites -- used to regulate discharges of stormwater into local waters. Industrial stormwater is particularly challenging to control because of the wide range of industrial sectors that are included, each of which produces a unique set of contaminants in stormwater, the report notes.

Under the MSGP, **industrial facilities** must implement a self-certified stormwater pollution prevention plan, which includes implementation of control measures to reduce pollution levels. Many facilities must also monitor their stormwater discharge for specific pollutants, and the results are evaluated against benchmark thresholds – the concentrations above

[4] National Academies of Sciences, Engineering, and Medicine. 2019. *Improving the EPA Multi-Sector General Permit for Industrial Stormwater Discharges*. Washington, DC: The National Academies Press.https://doi.org/10.17226/25355

which EPA has determined represent a level of concern "that could potentially impair, or contribute to impairing, water quality or affect human health from ingestion of water or fish."

THE REPORT RECOMMENDS THAT UNDER THE MSGP, EPA SHOULD REQUIRE:

- **industry-wide monitoring** for **pH, total suspended solids (TSS), and chemical oxygen demand (COD)** as basic indicators of the effectiveness of stormwater control measures employed on site. These parameters can serve as indicators of poor site management, insufficient stormwater control measures, or failures of these measures, which can lead to high concentrations of these and other pollutants. Industry-wide monitoring of these pollutants would also provide a baseline understanding of industrial stormwater management across all sectors.
- **a tiered approach to monitoring** that recognizes the varying levels of risk among different industrial activities and that balances the overall burden to industry and permitting agencies. Low-risk facilities could opt for a permit-term inspection by a certified inspector in lieu of monitoring. Those that do not qualify as low risk would conduct industry-wide monitoring for pH, TSS, and COD. Facilities in sectors that merit more pollution monitoring would also monitor for sector-specific benchmark parameters. Facilities that have repeatedly exceeded benchmarks, or large, complex sites with high potential for pollutant discharges would conduct more rigorous monitoring, potentially taking advantage of additional advanced monitoring and modeling strategies to assess the impacts of these sites[5].
- For stormwater monitoring the report recommend **to allow and promote the use of composite sampling for benchmark monitoring for all pollutants**. Multiple composite sampling techniques should be used that provide more consistent and reliable quantification of stormwater pollutant discharges compared to a single grab sample. EPA should develop "nonrepresentative storm" criteria to exclude monitoring for events that would not be representative offacility stormwater discharge (regarding extreme storms).

The report highlights that *the volume-weighted (or flow-weighted) pollutant concentration, also called the event mean concentration (EMC), provides the most consistent and comprehensive assessment of stormwater pollutant discharges and loads. Pollutant loads are important for understanding longer-term water-body impairments and toxicity concerns. The EMC is defined as the total pollutant mass discharged in the stormwater divided by the total runoff volume for the storm event, as measured at a specific outfall or measurement point. … Collection of composite volume-weighted samples over multiple storm events can provide a comprehensive understanding of annual pollutant discharge loads from a site and/or SCM performance over storms of different size.… Technology*

[5] https://www.nationalacademies.org/news/2019/02/epa-should-strengthen-the-science-in-its-permitting-program-for-industrys-management-of-stormwater-pollution-says-report

*verification for SCMs (stormwater control measures) used in **municipal stormwater requires monitoring of a minimum of 12 storm events** (composite sampling) over a range of storm intensities (with other constraints on type of storm, etc. [Water Quality Program, 2011]). … effectiveness of stormwater control measures implemented are most representative for water quality purposes when the sampling is conducted on discharges resulting from frequent storm events and not large extreme events. This event size may be based on a statistical review of long-term rainfall records to establish wet weather precipitation conditions when they become less relevant for water quality. **This criterion may be a storm of a certain return frequency such as a 10-year storm, or a multiple of the 90th percentile rainfall depth, or a multiple of the long-term average rainfall depth for the area.***

Composite sampling applicable for monitoring for all pollutants except those that transform or degrade rapidly or are especially time sensitive.

2.2 TARGET POLLUTANTS IN STORMWATER

Storms of different intensity transport pollutants at different times after runoff begins. Runoff from different parts of a facility reaches the sample point at different times. Additionally, different pollutants mobilize after different periods in contact with flowing water, i.e. the concentrations of different pollutants vary according to different rain events, catchment characteristics, pollutants properties and transportation pathways.

Pollutants, which are related to activity in question – type of activity, drainage and activity areas, imperviousness, roof surfaces, traffic volume are the main criterions in identifying parameters to be monitored, deciding what control measures to implement or determining their effectiveness. Improving the EPA Multi-Sector General Permit for Industrial Stormwater Discharges report recommends three industry-wide parameters: **pH**, **TSS** and **COD**. It was also suggested to consider advantages and disadvantages of conversion from COD to TOC (total organic carbon) monitoring.

Oils originate mainly from vehicles; **nitrogen** (N_t) and **phosphorus** (P_t) end up in stormwater from bulk fertilizers storage and loading activities. Stormwater from roofs is generally considered as clean but depending on the material, roofs can contribute to high metal Cu and Zn concentrations in stormwater. (Larm, 2000);

Considering stormwater quality, **suspended solids have a significant role**. Substantial removal rates of some pollutants such as heavy metals lead (Pb) and chromium (Cr), volatile oil hydrocarbons and polycyclic aromatic hydrocarbons (PAH) can be achieved simply by removing solids from stormwater. Phosphorus and suspended solids removal are also significantly correlated.

Metals in stormwater are generally present in various forms which has important implications to the design of the treatment method. Lead (Pb) is usually strongly bound to particles while cadmium (Cd), copper (Cu) and zinc (Zn) exist predominantly in dissolved form. The dissolved fraction is potentially the most toxic one due to its possible bioaccumulation in living organisms. Dissolved and particulate pollutants act differently. For example, dissolved metals, such as Cd are leached into stormwater at relatively low rainfall intensities, whereas higher intensities are required to mobilize particulate metals, such as Pb (Lind et al., 2001). Hence, the reduction of the dissolved fraction is of particular importance. In addition, several studies have shown that the rainfall depth (rainfall depth is the total depth of rainfall expressed in mm) is the most influential factor affecting the pollutant wash-off loads.

There are several factors affecting the concentrations of different pollutants. Concentrations decrease as total event rainfall increases whereas higher rainfall intensities can result in greater pollutant concentrations as rain events with higher intensities are able to mobilize more particulates which pollutants are usually bound to[6].

2.3 ADDITIONAL PRACTICAL INFORMATION ON AUTOMATED SAMPLING AND DEFINITIONS IN STORMWATER MANAGEMENT

The purpose of Standard Operating Procedure (SOP) for Automatic Sampling for Stormwater Monitoring developed by Washington State Department of Ecology[7](2018, Version 1.1) is to provide general guidelines and procedures on how automatic samplers work, how to install and program the instruments, and sample collection and processing procedures.

In order to use similar expressions and definitions in the project outputs it is suggested that the following terms be used adopted from the Washington State Department of Ecology publication, if appropriate:

DEFINITIONS

Automated Sampler: A portable unit that can be programmed to collect discrete sequential samples, time-composite samples or flow-composite samples.

Base flow: Flows occurring in the drainage after 48 hours with no measurable rainfall are defined as base flows. This flow may be consistent or intermittent within a stormwater conveyance system[8].

[6]Maria Suihko, Biofiltration for stormwater management in Finnish climate, Aalto University, Finland, 2016

[7]Automatic Sampling for Stormwater Monitoring, Standard Operating Procedure Version 1.1, Department of Ecology State of Washington, 2018; https://fortress.wa.gov/ecy/publications/summarypages/1810024.html

[8]Base flow is not typical in the conditions of Klaipeda port, because the stormwater is conveyed only from the territory of the companies located in the port area.

Best Management Practice (BMP): Physical, structural, and/or managerial practices that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater.

Composite Sample: Used to determine "average" loadings or concentrations of pollutants, such samples are collected at specified intervals, and pooled into one large sample, can be developed on time, flow volume or flow rate. Four types of composite samples can include:

1. Constant Time/Volume Proportional to Flow Rate,
2. Constant Volume/Constant Flow Volume Increment,
3. Constant Time/Volume Proportional to Flow Volume Increment
4. Constant Time/Constant Volume

Drainage Area: The area contributing runoff to a single point measured in a horizontal plane, which is enclosed by a ridge/edge line.

Event Mean Concentration (EMC): Pollutant concentration of a composite of multiple samples (aliquots) collected during the course of a storm. The EMC accurately depicts pollutant levels from a site and is most representative of average pollutant concentrations over an entire runoff event.

The EMC is defined as the total pollutant mass discharged in the stormwater divided by the total runoff volume for the storm event[9]:

The volume-weighted (or flow-weighted) pollutant concentration, also called the event mean concentration (EMC), provides the most consistent and comprehensive assessment of stormwater pollutant discharges and loads. Pollutant loads are important for understanding longer-term water-body impairments and toxicity concerns.

The EMC is defined as the total pollutant mass discharged in the stormwater divided by the total runoff volume for the storm event, as measured at a specific outfall or measurement point:

$$\text{EMC} = \frac{\text{Total Pollutant Mass}}{\text{Total Stormwater Volume}} = \frac{\int_0^{T_d} C\,Q\,dt}{\int_0^{T_d} Q\,dt}$$

where *C* is the pollutant concentration, *Q* is the flow rate, *t* is time, and *Td* is the storm duration. Determinations of pollutant mass load or the EMC requires comprehensive understanding of the flows and concentrations occurring over the entire storm event, which can be measurement intensive.

[9] National Academies of Sciences, Engineering, and Medicine. 2019. *Improving the EPA Multi-Sector General Permit for Industrial Stormwater Discharges*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25355

Event Mass Load (EML): calculated by multiplying event mean concentration (EMC) by event runoff volume.

Hydrograph: A graph of runoff rate, inflow rate or discharge rate past a specific point as a function of time.

Hyetograph: A graph of measured precipitation depth (or intensity) at a precipitation gauge as a function of time.

Outfall: Point source where an effluent or municipal separated storm sewer system discharges into receiving waters.

Pollutant Load: A mass concentration multiplied by the total volume of water passing by a certain point in time.

Stormwater: That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels or pipes into a defined surface water channel or a constructed infiltration facility. This includes stormwater runoff, snow melt runoff and surface runoff and drainage.

SOP document is used for collection of stormwater samples using programmable automated equipment for in-pipe stormwater discharge sampling and to some extent for open channel installations and covers a variety of technologies. Also describes programming and collection procedures when using automated samplers, (in common terms) for both flow-weighted and time-weighted sampling and base flow compositing, recommend sample volumes, etc.

It is emphasized that staff shall be familiar with standard operating procedures for water quality sampling and/or trained to collect representative environmental samples, demonstrate a competency for sample collection using appropriate sampling equipment and techniques.

3. RECOMMENDATIONS FOR STORMWATER MONITORING FRAMEWORK IN WISA PORT AREAS

Environmental monitoring programs for port and terminals sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to a particular project. The selection of parameters should be based on local site considerations and the objectives of the monitoring program, including local water quality issues and water uses of interest.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record- keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken[10].

3.1 SELECTION OF SAMPLING SITE

Each monitoring site will have individual characteristics that require a specific configuration of equipment and installation that best enables the collection of representative water quality samples. A successful location for automatic samplers features stable hydraulics and the ability to install sampling equipment. Other important factors to designate sampling location, i.e. sampling point where it discharges stormwater associated with bulk fertilizer storage, handling and loading activity. Dominant wind direction can be good to consider.

In general, preparation is critical to make sure that industrial stormwater monitoring is conducted properly and in a timely manner. Most needed preparatory work includes:

- Determination of drainage sub-basins within the area (ha) – terminal site map with identified bulk fertiliser handling area(s)
- Identification where runoff discharges from the site (known as “outlets”)
- Analysis of available monitoring data for the identification of most contaminated runoff outfalls
- Selection of the exact locations from which you will be collecting your stormwater samples (in cooperation with terminal operators)
- Pre-checking of sewer manhole accessibility, suitability for the deployment of the automated sampling equipment, tidal influence and other factors

Decision what and where to sample depends on partner’s suggestions, however, according to the project objectives, additional sampling of storm runoff from bulk fertilizer terminals should be a priority.

3.2 RECOMMENDED TYPE OF SAMPLING IN THE STUDY AREAS

To get proper picture of the amount of pollution in the stormwater it’s necessary to use sampling proportional to the rain or effluent volumes. Quarterly stormwater grab samples collected are inadequate to characterize stormwater discharges and the effectiveness of

[10] ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINES PORTS, HARBORS, AND TERMINALS, World Bank Group, February 2, 2017;

https://www.ifc.org/wps/wcm/connect/ddfac751-6220-48e1-9f1b-465654445c18/20170201-FINAL_EHS+Guidelines+for+Ports+Harbors+and+Terminals.pdf?MOD=AJPERES&CVID=lD.CzO9

the controls measures applied. Multiple composite sampling techniques are available that provide more consistent and reliable quantification of stormwater pollutant discharges compared to a single grab sample.

According to the project objectives, it is suggested to apply the **automated *time-weighted* or *flow-weighted* sampling** in the selected bulk fertilizers handling terminals outfall(s) and/or in the other by project partners proposed problematic stormwater management companies. The number of storm events to be monitored depend on the remaining time span of the project, partner's sampling equipment availability, qualification, etc.

3.3 SAMPLING PROCEDURE

The sampling must be performed during a measurable storm event that results in an actual discharge of stormwater from a site that follows the preceding measurable storm event by at least 72 hours (3 days), unless it is proved by permittee that less than a 72-hour interval is representative for local storm events during the sampling period.

The first sample should be taken after a rainfall of 0.2 mm and/or after 15 min – depending on rain intensity, and the next ones every 15 min (time-proportional) over an entire rain event, and the composite/pooled sample should be analysed in laboratory.

It is preferable to use 100% automatic flow-weighted sampling if possible (rain gauge connected to the automatic sampler), however “semi-automatic” system (manual rain forecast) can be a good alternative.

RECOMMENDED APPROACH WITH THE HELP OF AUTOMATIC SAMPLERS (USING THE EXAMPLE FROM ÅHUS PORT):

- Follow the weather forecast (or install rain gauge connected or not connected (wireless) to the sampler)
- Program the sampler to start at chosen time (example of automatic sampler: brand ISCO, model 6712, 24 bottles for samples)
- Take samples (120 ml) each 15 min
- If needed prepare composite hourly sample from 4 sub-samples collected each 15 min
- After storm event, download rain information from wireless rain gauge
- Check the time frame the sampler has been running
- Select samples worth analysing or analyse all (cost more)
- Analyse as many samples as possible to understand how the stormwater system behaves, each system is unique in its composition.

It is suggested to exclude snowmelt runoff from sampling activities as limited options to make tests due to less snowy winters, in some cases stormwater in the collection networks is frozen. At the same time snowmelt accounts for a small proportion of total rainfall per year. See annex - statistics from all three sites.

3.4 PARAMETERS TO MONITOR

When choosing parameters to be monitored in collected stormwater samples national and local regulations should be considered carefully. Pollutants, which are related to activity in question – type of activity, drainage and activity areas, imperviousness, roof surfaces, traffic volume are the main criterions in identifying parameters to be monitored, deciding what control measures to implement or determining their effectiveness.

The number of parameters will vary during the process. Based on activities in the area collecting stormwater give an idea what we could expect to find, but the first samples should be of a screening nature.

RECOMMENDED PRIMARY PARAMETERS FOR MONITORING IN ALL BULK FERTILIZERS TERMINALS

BASIC INDICATORS OF THE EFFECTIVENESS OF STORMWATER CONTROL MEASURES (ACCORDING TO USA NATIONAL ACADEMIES)

- Total suspended solids (TSS) – analysis within 24 hours
- Chemical oxygen demand (COD) / Biochemical oxygen demand (BOD) – analysis within 24 hours
- Total organic carbon (TOC)

BULK FERTILIZERS STORAGE AND LOADING ACTIVITIES:

- Total nitrogen (N_t)
- Total phosphorus (P_t)
- Cadmium (Cd) - HELCOM recommendation 31E/3, 'Cadmium in fertilisers', adopted 20 May 2010

ADDITIONAL OPTIONAL PARAMETERS FOR MONITORING IN BULK FERTILIZERS

- Ph
- Oil products – of traces of oil are visible in water
- Chlorides - current monitoring parameters in Klaipeda port fertilizers terminals
- Sulfates - current monitoring parameters in Klaipeda port fertilizers terminals

HEAVY METALS:

- lead (Pb) – as potentially toxic metal
- copper (Cu) – may be relevant in metals handling/cargo terminals
- chrome (Cr) – may be relevant in metals handling/cargo terminals
- zinc (Zn) – may be relevant in metals handling/cargo terminals and port areas
- nickel (Ni) – may be relevant in metals handling/cargo terminals
- arsenic (As),

- mercury (Hg) – may be relevant in petrochemical products handling/cargo terminals

Having identified the parameters, the next step is **to select a laboratory** to perform the tests. Selected lab shall be accredited or authorized by the designated responsible authorities for each analytical method, required for each selected parameter. Authorization assures that the lab is able to do quality testing using the standardized analytical methods. Other issues, like sampling equipment, preservation, holding time, safety, etc. should be clarified with selected lab in advanced.

3.5 NUMBER OF MEASURABLE STORM EVENTS TO GET REPRESENTATIVE DATA

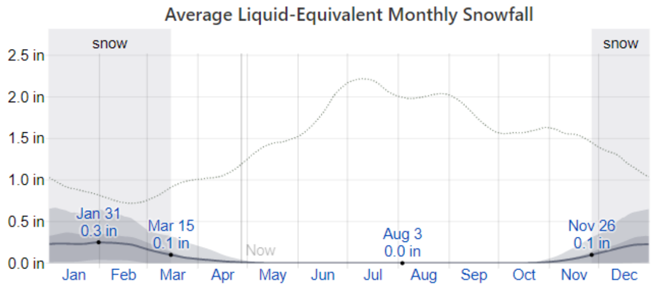
Collection of composite volume-weighted samples over multiple storm events can provide a comprehensive understanding of annual pollutant discharge loads from a site and/or SCM performance over storms of different size.... Technology verification for SCMs (stormwater control measures) used in municipal stormwater requires monitoring of a minimum of 12 storm events (composite sampling) over a range of storm intensities (with other constraints on type of storm, etc. [Water Quality Program, 2011]).

Number of storm event	Knowledge
1	Not much, an indication
3 for one year	Start to get a picture, are the event result similar or widespread?
5 for one year	Good knowledge of the behavior of the system
7 for one year	Know the system very well
12	Very good statistic base

For WISA project purposes the number of measurable storm events recommended to 5-7/year.

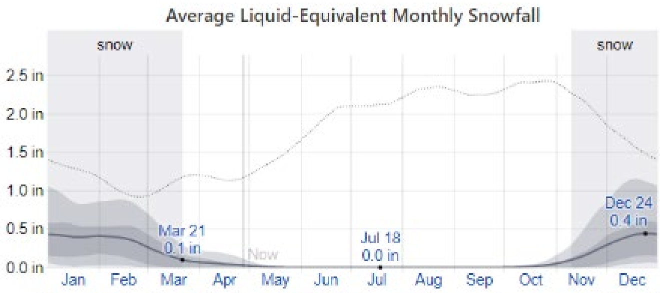
ANNEX (INFORMATION ABOUT SNOW COMES FROM WWW.WEATHERSPARK.COM)

GDYNIA



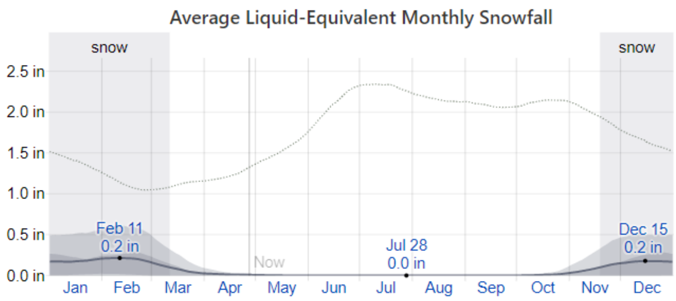
The average liquid-equivalent snowfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average rainfall.

KLAIPEDA



The average liquid-equivalent snowfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average rainfall.

KRISTIANSTAD



The average liquid-equivalent snowfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average rainfall.

Project WISA
WISA (Water Innovation System Amplifier) is a 3-year project that will contribute to a cleaner Baltic Sea by developing and testing new green technologies to reduce pollution by stormwater from ports and other large hard surfaces.

The Baltic Sea is one of the world's most polluted seas. More than 45 million tonnes of fertilizer pass through the ports of the Baltic Sea annually, and the handling contributes to the release of fertilizers and nutrients into the stormwater. This leads to eutrophication with extensive algal blooms and dead seabed.