GRACE grant no 679266

SmartBuoy technology and integration with oil spill detection networks

D1.3

WP1: Oil Spill detection, monitoring, fate and distribution

Prepared under contract from the European Commission
Contract n° 679266
Research and Innovation Action
Innovation and Networks Executive Agency
Horizon 2020 BG-2014-2015/BG2015-2

Project acronym:	GRACE
Project full title:	Integrated oil spill response actions and environmental effects
Start of the project:	01 March 2016
Duration:	42 months
Project coordinator:	Finnish Environment Institute (SYKE)
Project website	http://www.grace-oil-project.eu

Deliverable title:	SmartBuoy technology and integration with oil spill detection networks
Deliverable n°:	D1.3
Nature of the deliverable:	Report
Dissemination level:	Public
WP responsible:	WP1
Lead beneficiary:	MTOY
Due date of deliverable:	28.02.2017
Actual submission date:	28.02.2017

Deliverable status:

Version	Status	Date	Author	Approved by
1.0	version for comments	25.1.2017	Luode Consulting Oy	Antti Lindfors
1.1	Final draft	30.1.2017	Meritaito Ltd	Seppo Virtanen
1.2	Amended version	02.02.2017	Luode Consulting Oy SYKE / Harri Kankaanpää	Antti Lindfors / Seppo Virtanen
1.3	Amended versio	27.2.2017	Luode Consulting Oy Joose Mykkänen	Antti Lindfors and steering group 27.02.2017

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1. Executive summary

System integrations for automatic hydrocarbon monitoring buoy were completed for a GSM based data transmission system in October 2016. A new cleaning system to prevent bio-fouling was developed. System uses pressurised air burst to clean optical window of the fluorometer. System was laboratory tested and installed inside a SeaHow Smart Buoy and deployed in October 2016 for first wintertime trials.

SeaHow prepared moorings and installation of monitoring platform. The system was installed on the 20th of October using the vessel Seili. After installation laboratory samples were collected. The Smart Buoy has been visited two times until January 2017 for manual maintenance.

Based on the first results, the system has been working without any technical problems or data transmission errors. Results are visualized on on-line data service as raw data and calibrated readings based on measured turbidity records and laboratory samples. As more reference samples are collected, readings will be re-calibrated. Preliminary calibration is done based on single sample.

Data streaming from a SmartBuoy is done via Luode dataservice. Data quality check is done twice a day and data is presented thru password protected www-page. Until now over 2900 hourly hydrocarbon readings have been collected, together with additional 5800 salinity and temperature readings. Only one false reading out of 2900 has been flagged out from results. Floating debris or ice in front of the optical window can cause this kind of errors in measured signal.

Based on the collected hydrocarbon concentration data, values remained more or less constant and no sign of oil contamination was detected. General level of the collected total hydrocarbon data (2.3-3.2 µg/l hydrocarbons) was anyway above the level detected with the laboratory analyses (0.27-1.0 µg/l hydrocarbons). River flows and runoff from land areas are carrying organic carbon and turbidity to coastal sea areas which have an impact on fluorescence in hydrocarbon detection. The impact of these interference parameters can be eliminated in sensor calibration when more reference data is available.

Figure 1. Testing of monitoring devices inside a SmartBuoy. Picture Seppo Virtanen / SeaHow

2. Principles of oil detecting smart buoys and visions (applications) for their use

Smart Buoy concept principal

Smart Buoy is a combination of robust polyethylene spar buoy and versatile selection of monitoring sensors with mobile communication technology (Fig. 1). Network of Smart Buoys enable intelligent solutions for many applications, like ENC, VTS, SAR, Ports etc.

Background

In Oil Spill Recovery the early warning and the quick start of response actions play crucial role in terms of Oil Spill recovery effectiveness and the limitation of the negative effects of the Oil Spill. A network of Smart Buoys with Oil Spill detection sensors could be the sentinel that never sleeps.

Also direction and magnitude of current as well as prevailing wave height play an important role in safe navigation. Real-time and In-situ data would be highly appreciated, since mariners know well that these factors can vary significantly depending on wind direction, archipelago, and shape of the coastline.

Modern sensor and telecommunication technology enables all that and much more like location of the buoy, status of lantern, battery charge, water temperature, Oil Spill detection, oxygen content, algae detection, Turbidity, Salinity.

Sensor development enables new applications

Monitoring data from autonomous Smart Buoy stations can be delivered continuously 24/7 to almost "where ever", like Port Operators, SAR operators, Maritime Authorities or VTS-centers. Data transmission can be arranged according specifications, with GSM-modem to web-server or with AIS-modem to local network or by using satellite connection.

The use of "normal" navigation buoy as a sensor platform saves costs both in investment and maintenance. Extra costs needed to modify navigation buoy body for the sensor implementation are only about 30% higher compared to the manufacturing of standard navigation buoys

3. Description of test with oil sensing SmartBuoy in winter conditions in the Baltic Sea

Neste Porvoo Oli refinery harbour master and environmental specialists were contacted in order to have access to use sea area outside the refinery for sea trials. After site survey, a permission was granted for winter period 2016-2017. Suitable installation location to test winter tolerance of system was found right outside the seaport of refinery (Fig 2).

Sea trials are done with Trios EnrivoFlu hydrocarbon sensor which is installed together with YSI 600 series conductivity and temperature sensor (Fig 4). Sensors are placed inside of the buoy in a vertical monitoring well with open flow through pipe enabling continuous seawater exchange (Fig 4). Monitoring depth is 2.5 – 3.0m depending on current sea level. Hydrocarbon sensor detects total concentration of polyaromatic hydrocarbons suspended in seawater. In addition to hydrocarbon monitoring, salinity and temperature data is collected to verify the sensitivity of the system for changes in background signals as monitoring area is located close to river mouth.

Figure 2. Monitoring location, Port of Neste Porvoo oil refinery. Picture Luode Consulting / MML.

Figure 3. Left: Trios EnviroFlu hydrocarbon sensors and right: YSI 600 multiparameter sonde.

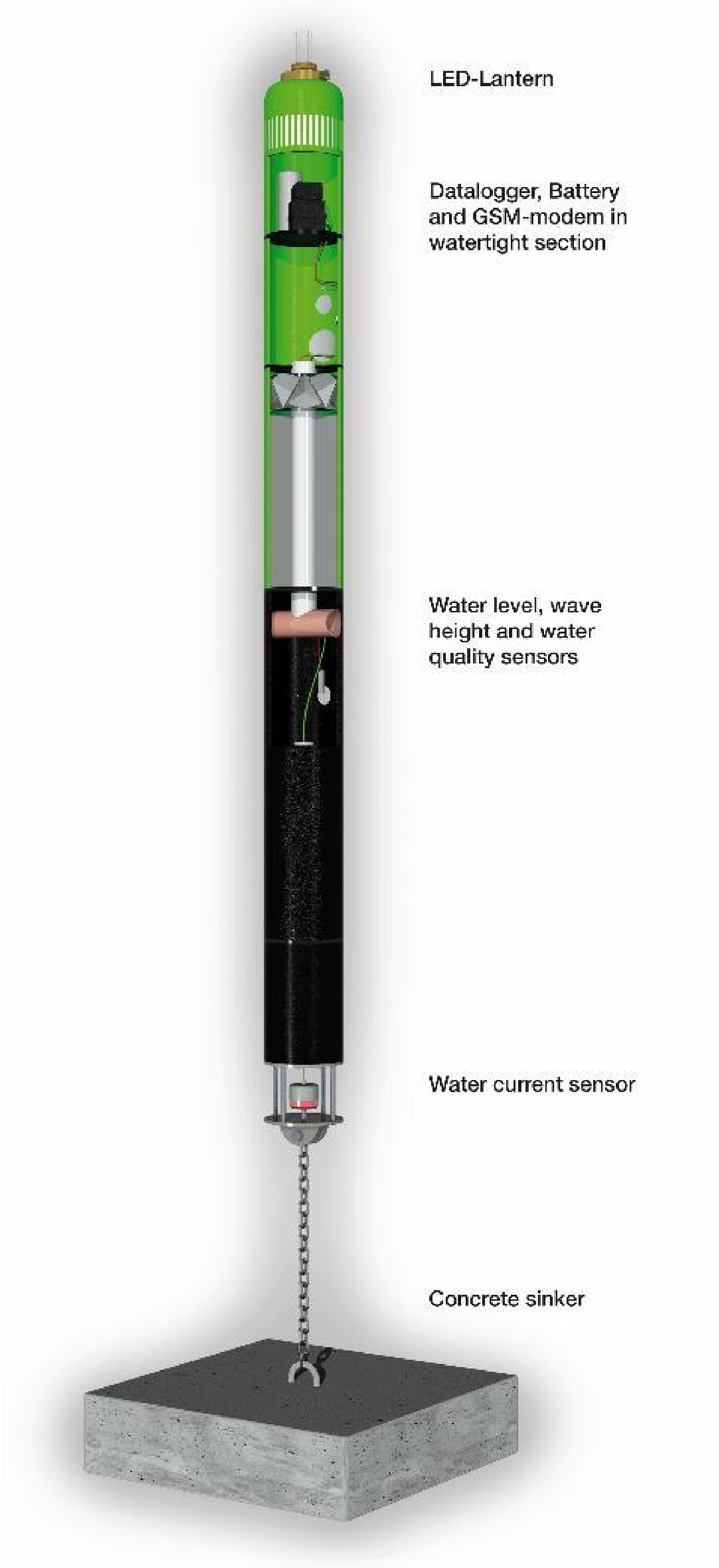


Figure 4. Schematic figure of SmartBuoy system. Sea trials utilizes water quality monitoring option, but the system can be used simultaneously also for water level, current and wave height monitoring.

SeaHow prepared moorings and installation of monitoring platform. System was installed on the 20th of October from vessel Seili (Fig 5). After installation laboratory samples were collected (Fig 6). The Smart Buoy has been visited two times until January 2017 for manual maintenance.

Figure 5. Preparation of moorings on board the buoy tender vessel "Seili". Picture Seppo Virtanen / SeaHow

Figure 6. Water sampling for laboratory tests. Picture Seppo Virtanen / SeaHow

4. Reference water quality data

Water sampling

Seawater samples were collected from the deployment site for further laboratory analyses to be used in sensor calibration and data validation. Two parallel samples of surface seawater were collected for chemical laboratory analyses (PAHs) on October 20 2016, right after the buoy was deployed. Another set of samples for the chemical analyses (total oil, DOC and TOC) were collected at the buoy site (5−10 m away from the buoy; approximately 60°18.77' N, 25°33.21' E; Kilpilahti 1) at a depth of 1.5−2 m and from a pier (60°18.57' N, 25°33.15' E, about 350 m south of the buoy location; Kilpilahti 2) within the Neste Porvoo oil refinery's coastal waters on January 10, 2017. Two parallel water samples were collected from the two sites.

Total oil in seawater

Analyses of seawater sample collected on January 10, 2017 for total oil concentration was performed according to the Finnish marine monitoring protocol (fluorometry) that is based on the original procedure published by the intergovernmental oceanographic commission (IOC, 1984) and used in Finnish HELCOM COMBINE monitoring programme. The results are presented in Table 1. The results indicate slight contamination of seawater by PAH compounds in sample collected closer to the Kilpilahti shoreline (pier) with concentrations (0.98±0.15 µg/l). The IOC oil contamination threshold is 1.0 µg/l. At the buoy site the total oil concentrations were lower (0.31±0.05 µg/l), indicating no contamination by PAH-containing oil products. That latter concentration is close to or somewhat lower that is found in the northern Baltic Sea in Finnish

HELCOM monitoring during winter period. The concentration is slightly lower than has been detected in the central Gulf of Finland within the past 15 years, and can be considered to be at the background concentration level currently prevailing in the area.

Table 1. Total oil concentrations determined according to the IOC/HELCOM protocol on January 10, 2017. The error of determination is based on the method reproducility.

Sample site	Total oil parallel 1 µg/l	Total oil parallel 2 µg/l	Total oil average ± error µg/l
Kilpilahti 1 (buoy)	0.27	0.35	0.31±0.05
Kilpilahti 2 (pier)	1.00	0.96	0.98±0.15

PAHs in seawater

The concentrations of PAHs remained under the level of quantification (LOQ), i.e. very low in samples collected at the buoy site on October 20, 2016. The second replicate sample showed a below-LOQ concentration of napthalene at 0.001 µg/l. These results are close to what have been detected in samples from the pelagic Gulf of Finland in the 21st century, and indicate very low if any contamination of seawater by oil.

Dissolved organic carbon (DOC) and total organic carbon (TOC) in seawater

Analyses on DOC and TOC of samples collected on January 10, 2017 were performed at SYKE laboratory in Oulu. The results are summarized in Table 2. The DOC and TOC concentrations in the parallel samples are very uniform. Most of the carbon in the seawater samples was present in dissolved form.

Table 2. DOC and TOC in samples from Kilpilahti, January 10, 2017.

Sample ste	LAB code	DOC DOC-262K mg/l	TOC TOC-327K mg/l
Sköldvik	DOK1	5.30	5.80
Sköldvik	DOK2	5.40	5.70
Sköldvik	DOK3	5.20	5.70
Sköldvik	DOK4	5.40	5.70

5. Results of the test with oil sensing SmartBuoy in winter conditions in the Baltic Sea

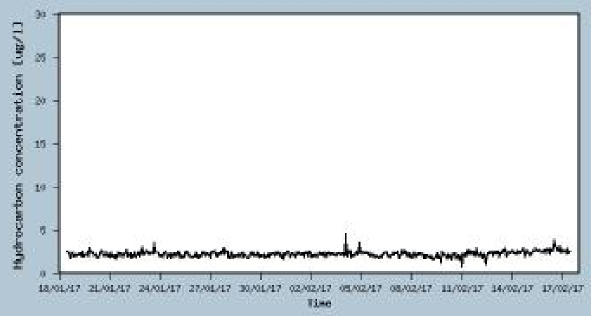
Based on the first results, the system has been working without any technical problems or data transmission errors. Results are visualized on on-line data service as raw data and calibrated readings based on measured turbidity records and laboratory samples. As more reference samples are collected, readings will be re-calibrated. Preliminary calibration is done based on single sample.

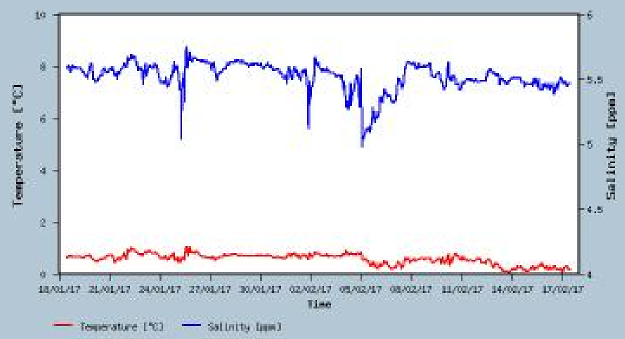
Data streaming from a SmartBuoy is done via Luode dataservice. Data quality check is done twice a day and data is presented thru password protected www-page (Fig 7). Until now over 2900 hourly hydrocarbon readings have been collected, together with additional 5800 salinity and temperature readings. Only one false reading out of 2900 has been flagged out from results. Floating debris or ice in front of the optical window can cause this kind of errors in measured signal.

Based on the collected hydrocarbon concentration data, values remained more or less constant and no sign of oil contamination was detected. General level of the collected total hydrocarbon data (Fig. 8) was anyway above the level detected with the laboratory analyses (Table 1). River flows and runoff from land areas are carrying organic carbon (Table 2. DOC&TOC) and turbidity to coastal sea areas which have an impact on fluorescence in hydrocarbon detection. The impact of these interference parameters can be eliminated in sensor calibration when more reference data is available.

LOG OUT FRONTPAGE

Oil Buoy





Latest results

Date and time	Hydrocarbons RAW [µg/l]	Salinity [‰]	Temperature [°C]	Hydrocarbons backgroung compensated [µg/l]
17.02.2017 12:00	30,6	5,47	0,2	2,6
17.02.2017 11:00	30,5	5,47	0,2	2,5
17.02.2017 10:00	30,3	5,47	0,2	2,3
17.02.2017 09:00	30,7	5,46	0,2	2,9
17.02.2017 08:00	30,5	5,45	0,3	2,4
17.02.2017 07:00	30,3	5,45	0,3	2,3
17.02.2017 06:00	30,6	5,48	0,3	2,6
17.02.2017 05:00	30,6	5,48	0,3	2,7
17.02.2017 04:00	30,5	5,48	0,3	2,6
17.02.2017 03:00	30,6	5,47	0,3	2,7
17.02.2017 02:00	30,3	5,47	0,1	2,5
17.02.2017 01:00	30,5	5,48	0,1	2,5
17.02.2017 00:00	30,8	5,51	0,2	2,8
16.02.2017 23:00	30,7	5,52	0,2	2,8
16.02.2017 22:00	30,3	5,51	0,2	2,5
16.02.2017 21:00	30,8	5,49	0,2	3,2
16.02.2017 20:00	30,6	5,47	0,2	2,6
16.02.2017 19:00	30,6	5,43	0,2	2,6
16.02.2017 18:00	30,9	5,43	0,2	2,8
16.02.2017 17:00	30,9	5,47	0,2	3,0

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Browse the service history of the station

Figure 7. Screen capture from Luode on-line data service. Picture Luode Consulting Oy.

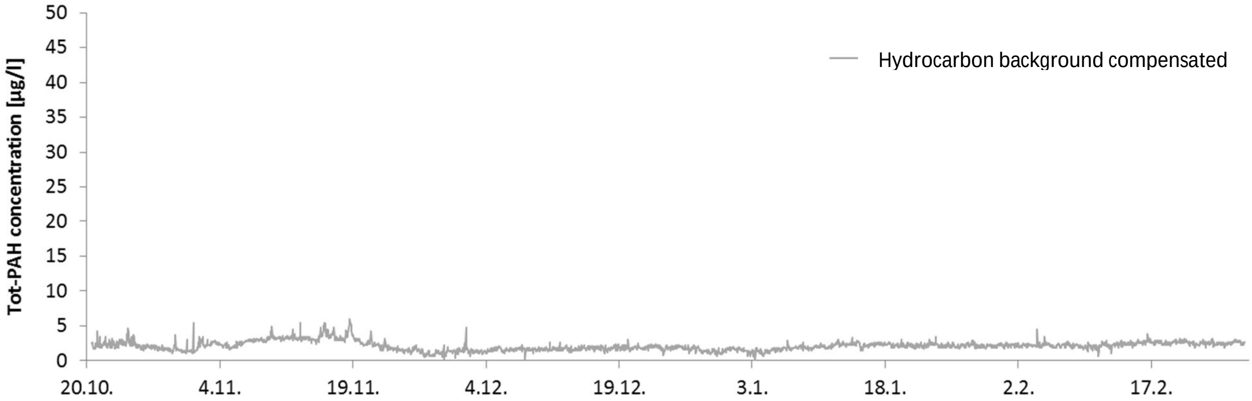

Figure 8. Collected hydrocarbon data processed with initial calibration. The data will be re-calibrated when more reference data is available.

6. Discussion and conclusions and further development work

First GSM-based system has been successfully launched for sea-trials and based on preliminary results all systems have been performing well. Automatic cleaning showed that pressurized air can keep the optical detection window clean and thus the maintenance interval can be kept reasonable.

No sign of oil contamination was detected, but the results show that hydrocarbon detection with fluorometers in coastal sea areas requires local calibration and understanding the impact of interference parameters such as organic carbon and turbidity.

Next model with satellite data transmission is under development and will be ready for sea trials later in year 2017. System integration is ongoing and first bench tests will start in April-May 2017.

References

Intergovernmental Oceanographic Commission. 1984. Manual for monitoring oil and dissolved/dispersed petroleum hydrocarbons in marine waters and on beaches. Procedures for the petroleum component of the IOC Marine Pollution Monitoring System (MARPOLMON – P) IOC, Manuals and Guides 13, UNESCO, 35 pp.

Appendix: Concentrations of PAHs determined using a GC-MS^{n} protocol.

			1-methylnapthtalene	2-methylnapthtalene	Anthracene	Acenaphtene	Acenaphtylene	Benzo[a]antracene	Benzo[a]pyrene	Benzo[b]fluoranthene	Benzo[e]pyrene	Benzo[ghi]perylene	Benzo[k]fluoranthene	Dibenzo[a,h]antracene	Phenantrene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Chrysene	Naphtalene	Perylene	Pyrene	Triphenylene
			1MNA-1613X	2MNA-1614	ANTR-1478	ANP-1479X	ANY-1480X	BAA-1481X	BAP-1482X	BBF-1483X	BEP-1618X	BGHI-1484X	BKF-1485X	DBAH-1486	PHN-1487X	FLUO-1488	FLUR-1489X	IP-1490X	CHRY-1491	NAFT-1492	PER-1619X	PYR-1502X	TRF-1617X
LIMS number	Customer code	Sampling date	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
1416-02985-001	Kilpilahti A	21.10.2016	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.002	<0.005	<0.002	<0.002	<0.005	<0.002	<0.005
1416-02986-001	Kilpilahti B	21.10.2016	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.002	<0.005	<0.002	<0.002	<0.005	<0.002	<0.005