SOILS2SEA DELIVERABLE NO. 3.3

BONUS
SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

Prototype of new sensors for flux measurements of N and P

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Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams

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Prototype of new sensors for flux measurements of N and P

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Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams

This report is a publicly accessible deliverable of the Soils2Sea project. The present work has been carried out within the project ‘Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams (BONUS Soils2Sea)’, which has received funding from BONUS, the joint Baltic Sea research and development programme (Art 185), funded jointly from the European Union’s Seventh Framework Programme for research, technological development and demonstration and from Innovation Fund Denmark, The Swedish Environmental Protection Agency (Naturvådsverket), The Polish National Centre for Research and Development, The German Ministry for Education and Research (Bundesministerium für Bildung und Forschung), and The Russian Foundation for Basic Researches (RFBR).

De Jonge H, Prototype of new sensors for flux measurements of N and P. BONUS SOILS2SEA Deliverable 3.3. Eurofins Environment, Galten, Denmark, January 2018, www.Soils2Sea.eu

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1. Background and objectives

Monitoring of nutrient loads requires measurements of concentration and flux. Such data are collected on a routine basis in national monitoring programs using measurements of discharge and concentrations in streams. These measurements can be relatively accurate, if the concentration measurements are performed with high frequency, e.g. using ISCO samplers. However, such measurements are rather expensive, and therefore the network of such stations is usually not very dense, typically ranging from 1 station per 100 km^2 to less than one station per 10,000 km^2.

The BONUS SOILS2SEA project investigates the potential for spatially differentiated regulation as a smart approach to design more cost-effective mitigation measures. In this respect measurements of nutrient loads from tile drains and small catchments (< 1 km^2) is interesting. Therefore, there is a need to find measurement systems that are much cheaper than the traditional stream discharge plus ISCO samplers. The passive sensor technique developed by Sorbisense is very relevant in this respect. Sorbisense sensors has proven useful for cheap monitoring of e.g. N and P concentrations in drain water and groundwater (De Jonge and Rothenberg, 2005; Rozenmeijer et al., 2010).

The objective of the present study has been to further enhance the Sorbisense sensor technique to allow flow proportional measurements of N and P loads in tile drains by developing a new sensor for flux measurements and make a real-life field test in one of the project study catchments in Norsminde.

2. Descriptions of prototype sensors

The “FlowCap” sampling concept is based on a combination of the existing Sorbicell with the Sutro flow-weir configuration. The Sorbicell (Figure 1) is a modern flow-through passive sampler cartridge that accumulates mass on a sorbent phase and simultaneously “records” the flow volume through the loss of tracer salt initially stored in the cartridge (see picture below). The Flowcap (Figure 2) functions as an end-of-pipe flow weir over which the drainage water passes. The convex Sutro profile controls the height of the water level in the unit in a unique fashion, in that there is a linear relationship between the Flow rate *Q* from the drainage pipe (volume/time) and the height of the water level (*h*) in the unit. By installing the Sorbicell level with the bottom of the Sutro profile, there is a linear relationship between Q, and the hydraulic pressure to which the Sorbicells are exposed. A field installation is seen in Figure 3.

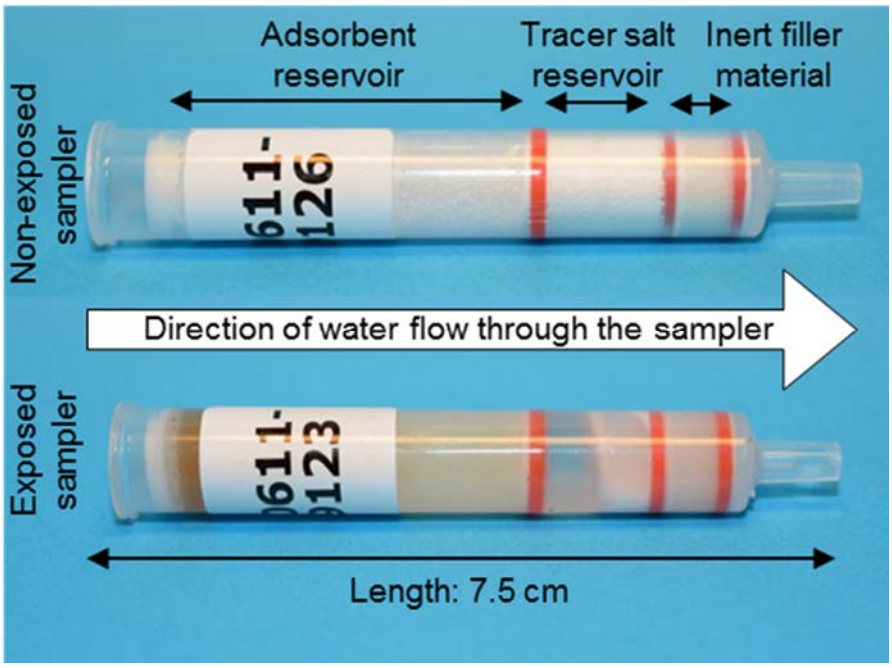


Figure 1. Picture of non-exposed (top) and exposed (bottom) Sorbicell. The cartridge shown is of type Sorbicell NiP, containing and ion-exchange resin for capturing of nitrate and phosphorous.

Figure 2. Pictures of FlowCap mounting unit prototypes with Sutro profile (left) and mounting sockets for Sorbicells (right).

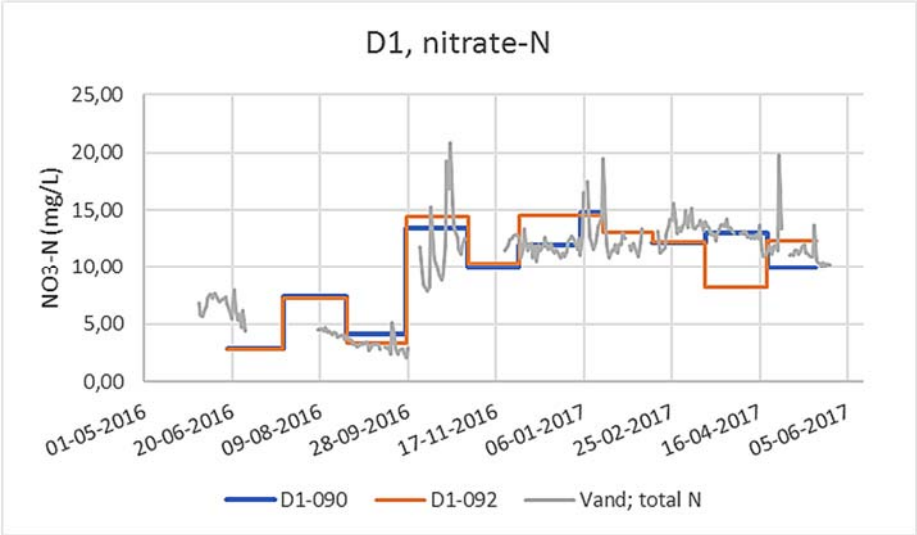
Figure 3. Picture of FlowCap installation at tile drain location D8, Norsminde catchment, Denmark.

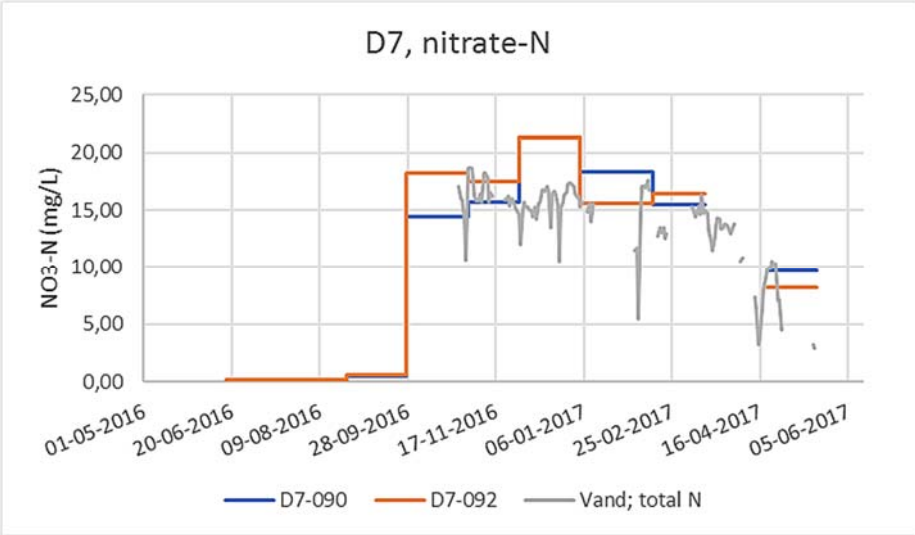
3. Test results and discussion

Flow weir units, "*FlowCaps*", for Ø110 and Ø160 drainages pipes were constructed. At the Norsminde Catchment, 3 locations (D1, D7, D8 – see Figure 4) were instrumented in 2015. During a full scale monitoring and performance test, location D1, D7 and D8 were equipped with duplicate SorbiCells and sampled throughout the drainage season 2016-2017 with monthly sampling intervals. At the D1 location, a revised scaled-up prototype version of the system with a capacity of 4.300 m^3 day^{-1} was installed January 2017.

Figure 4. Location of the three test sites, D1, D7 and D8 shown on Google Maps. The urban area at the right side of the map is the town of Odder.

All SorbiCells were analysed in the laboratory and results were compared to regular water samples (ISCO sampler) and flow data collected by Aarhus University. Figure 5 shows results of comparisons for nitrate concentrations at the three sites, while Figure 6 shows the comparisons for water flows in the drain pipes at the three locations.





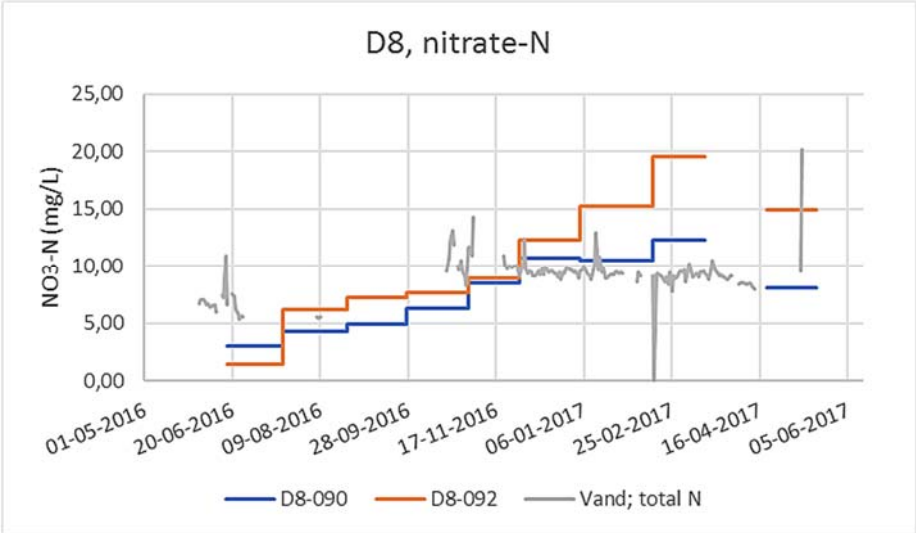


Figure 5. Graphs of nitrate concentrations in drain D1, D7, D8; Fensholt Denmark. Blue line, results of SorbiCell NiP (type 090); Red line, result of Sorbicell NiP (type 092); grey line, water samples (total N).

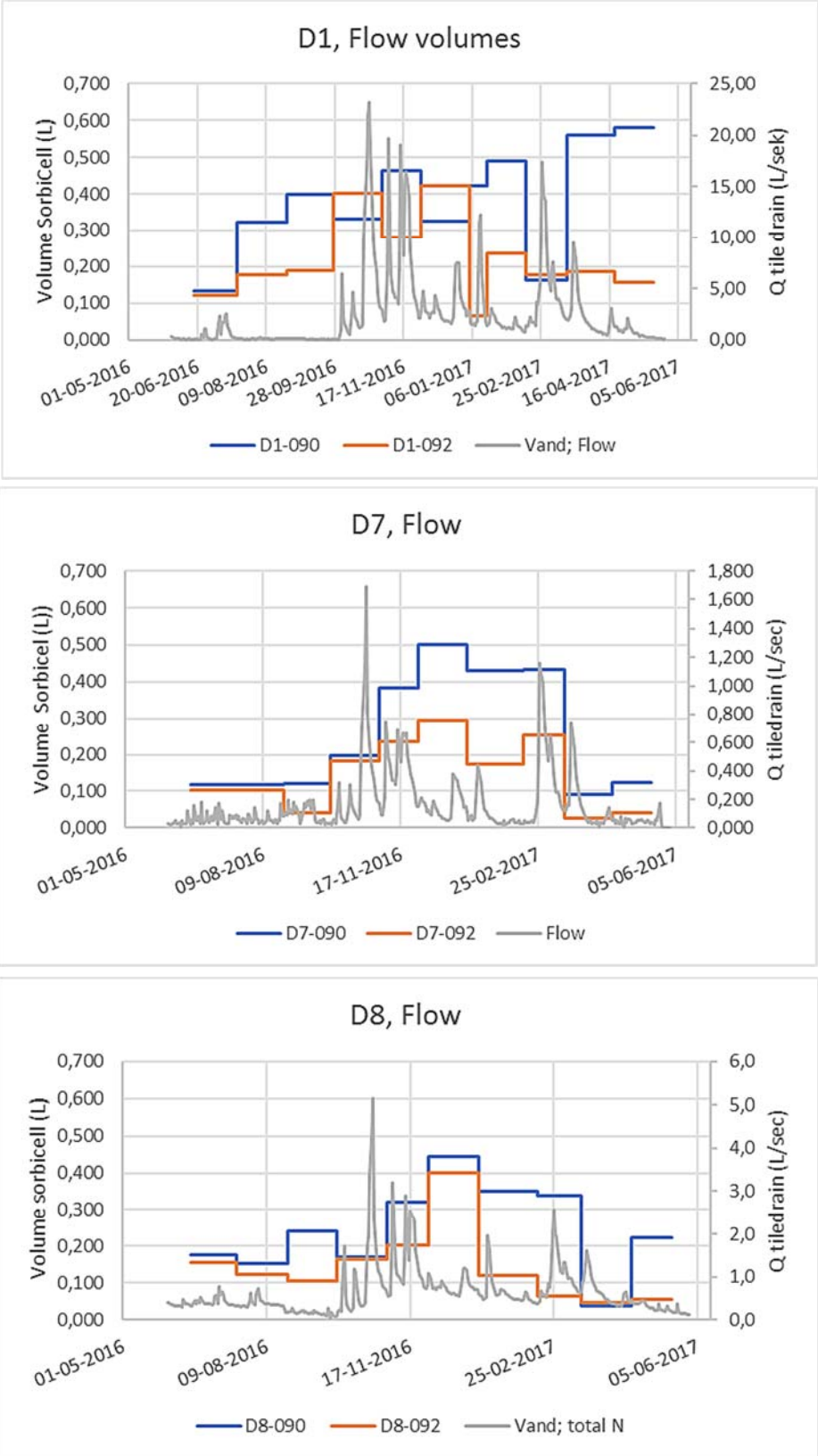


Figure 6. Graphs of flow volumes in drain D1, D7, D8; Fensholt Denmark. Blue line, results of SorbiCell NiP (type 090); Red line, result of Sorbicell NiP (type 092); grey line, water flow Sensor (Data Aarhus University).

Results from nitrate concentrations show close resemblance of Sorbicell results compared to water samples (Figure 5). Both absolute levels as well as temporal patterns are well reproduced and comparable for both methods. The Sorbicell type 090 (lowest hydraulic resistance) generally shows best results but in most cases results from type 090 and 092 do closely match – with RDS on average 14% of measured result.

The results from Sorbicell volumes and flow sensor show no clear resemblance, both absolute levels as temporal patterns are not well reproduced, especially not the peak flow events during the winter period (Figure 6). The Sorbicell type 090 (lowest hydraulic resistance) generally shows highest volumes, as was expected. But the temporal pattern of type 092 is generally best correlated with flow variations. The lack of general correlation suggest that the flow of the Sorbicells has been restricted, possibly due to frost conditions in the winter.

The present dataset shows that Sorbicell is a useful tool for measuring nitrate concentrations in field tile drains. The FlowCap mounting has been functioning well as a working prototype. However, the SorbiCell flow has been restrained probably due to freezing periods in the winter. At the present state of technology, the unit cannot yet be used for direct estimations of solute loads. Hence, Sorbicell results should be combined with other methods in order to calculate the total mass load leaving agricultural fields.

4. References

De Jonge H, Rothenberg G (2005) New device and method for flux-proportional sampling of mobile solutes in soil and groundwater, Environmental Science & Technology, 39, 274-282, 10.1021/es049698x, 2005.

Rozemeijer J, van der Velde,Y, de Jonge H, van Geer F, Broers HP, Bierkens M (2010) Application and Evaluation of a New Passive Sampler for Measuring Average Solute Concentrations in a Catchment Scale Water Quality Monitoring Study, Environmental Science & Technology, 44, 1353-1359.

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