Advanced modelling of wave overtopping for climate resilient coastal defence systems

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Only 67 km long, the Belgian coast represents a significant touristic, socio-economic and cultural value for the densely populated country. Historically, the coastal land-use planning was much less restrictive than that of the neighbouring countries. This caused a very high degree of local coastal development from the end of the 19th century on and increased considerably after the Second World War, with the rise of middle-class mass-tourism and apartment buildings on the sea dike. In addition, since the 1970's, beach nourishment was adopted as a complementary coastal protection scheme: millions of cubic meters of sand were artificially added to the beach and foreshore and pushed the sea further away from the sea dikes. This resulted in the typical Belgian coastal appearance as it is known today: an almost continuous row of high rise apartment buildings fronted by a sea dike with promenade and a mildly sloped beach.

The typical Belgian coastal defence system, in the urbanised coastal areas, is a nourished beach providing a long and (very) shallow foreshore in front of a sloped sea dike with promenade and buildings and/or storm wall(s) close to the dike crest. Climate change is expected to keep causing sea level rise and an increase in storm occurrence and intensity. The Belgian coastal defence system against flooding is therefore being adapted, according to the masterplan for coastal safety [1], by a combination of a beach nourishment and dike crest level increase by a storm wall.

In the functional design of these storm walls, the height of the storm wall is calculated by determining the wave overtopping, which is limited to a specific safety criterion. The wave impact forces need to be resolved for the design of the structural stability of the storm wall. Current state of the art methodologies to calculate the wave overtopping still contain simplifications that are too conservative for this kind of cross-section. For example, they do not take into account some important physical processes resulting from the complex geometry of the typical Belgian coastal profile. In addition, the design criterion for wave overtopping has focussed on the mean overtopping discharge. Individual wave overtopping volumes have not been investigated into much detail yet.

The present research focusses on advanced numerical modelling of wave overtopping over and wave forces on this typical Belgian coastal defence system, resolving the hydrodynamic flow in full 3D (or 2DV, disregarding the alongshore horizontal dimension). This should allow for a much more accurate prediction of the mean overtopping discharge and individual overtopping volumes. Furthermore, hydrodynamic experiments in both a wave flume (2D) and wave basin (3D) in addition to field measurements will be performed to provide data with which the numerical method can be verified. Field tests do not suffer from scale effects nor from model effects and are a crucial source of information to be integrated in the overall validation of the methodology. The field measurements will include an artificial dike constructed on the beach, close to the high water line, to allow measurement of wave overtopping and wave impact on the short term.

This research is part of the fundamental strategic research project ''CREST - Climate REsilient coast (www.crestproject.be): wave action in a changing climate: effects on the dynamics of the coast and implications for future safety strategies'', funded by the Flemish Agency for Innovation by Science and Technology (formerly known as IWT, now part of VLAIO, Flanders Innovation & Entrepreneurship).

Keywords: wave overtopping; wave impact; storm wall; very shallow foreshore; numerical wave modelling; hydrodynamic experiments; field measurements

Reference

- MDK - Afdeling Kust, Flanders Hydraulics Research, 2011. Masterplan Kustveiligheid – Kustveiligheidsplan. MDK - Afdeling Kust & Flanders Hydraulics Research.

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PREFACE

This is the 'Book of Abstracts' of the 17th edition of the VLIZ Marine Science Day, a one day event that was organised on 3 March, 2017 in VIVES, Brugge.

This annual event has become more and more successful over the years. With more than 400 participants and more than 100 scientific contributions, it is fair to say that it is the place to be for Flemish marine researchers and for the end-users of their research. It is an important networking opportunity, where scientists can meet and interact with their peers, learn from each other, build their personal professional network and establish links for collaborative and interdisciplinary research.

Marine scientists from all Flemish universities and scientific institutes – and representing all marine science disciplines – have contributed to this volume. The book thus illustrates the diversity, quality and relevance of the marine sciences in Flanders (and Belgium): it provides a beautiful and comprehensive snapshot of the state-of-the-art of marine scientific research in Flanders.

Pre-doc and post-doc scientists present their research in an exciting way and communicate their fascinating science – and its importance to society – to the wider public. We thus hope to demonstrate the excellence of Flemish marine science and to increase its national and international visibility.

The volume of research that is presented here holds a great promise for the future. It shows that marine science is a very lively discipline in Flanders, and that a new generation stands ready to address the grand challenges and opportunities that our seas and oceans represent.

New this year are the Brilliant Marine Research Ideas, an initiative sponsored through the philanthropy scheme of VLIZ. We are proud to announce that an initial batch of 4 ideas will be sponsored. We'll hear about the results in the next edition of the Marine Science Day.

I want to congratulate all participants with their contributions, and I invite them all to become members of VLIZ and to actively participate in our events and activities in the future.

Bruges, 3 March 2017
Prof. Dr Jan Mees
General Director VLIZ

TABLE OF CONTENTS

VLIZ Master Thesis Awards

VLIZ North Sea Award

Oral, Demo and Poster Presentations

Development of diffusive gradients in thin films (DGT) passive samplers for simultaneous measurement of Platinum, Palladium, Rhodium and Mercury in surface water

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Increasing anthropogenic activity often has detrimental effects on human health and the environment due to the accompanying emissions of toxic compounds. The increased application of Platinum Group Elements (PGEs) (Pt, Pd, Rh, Ru, Os and Ir) in the last decades, especially as car catalysts but also in other applications, makes it necessary to monitor the concentration of these elements in the environment, investigate their environmental transformations and bioavailability. Mercury (Hg) is also recognized as one of the most toxic trace elements, whose natural cycle has been altered by anthropogenic activities. Complex biogeotransformations result in different chemical species, with varying toxicities and mobility, which need close monitoring. The concentration of these elements usually extremely low in the aquatic environment, which makes the analysis challenging.

As the toxicity, bioavailability and the cycle of environmental contaminants can strongly be influenced by their chemical speciation, in recent years, the importance of speciation analysis has been recognized by the environmental monitoring and assessment community, leading to the development of an increasing number of speciation techniques. The in situ passive sampling technique diffusive gradients in thin films (DGT) as a speciation tool is based on the binding of labile metal species on a resin gel layer via the diffusion through a diffusive hydrogel (agarose or polyacrylamide) using Fick's Law. The concentration gradient built between the bulk solution and the resin gel makes pre-concentration of solutes possible. Using Fick's law, the time-weighted average concentrations of labile metal species can be obtained in situ. This technique has been widely used to assess trace elements such as Cd, Cu, Ni, Pb, Co, Zn in aquatic systems, but never been applied to test PGE elements until now.

The aim of this study was to develop the DGT technique for the assessment of PGE and Hg using two novel resins R14 and R20, which were designed specifically for above elements. This implies that the binding of the PGEs to the resin is strong, irreversible, almost instantaneous and the accumulated metals amounts are well below the capacity of the resin. The method development involves several different steps: 1) selection of an appropriate diffusive gel 2) the selection of an appropriate resin or binding phase for the PGEs and Hg, 3) development of an efficient elution method for the PGEs and Hg from the resin gel, 4) evaluation of the linear response in function of the deployment time, 5) determination of diffusion coefficients for the PGEs and Hg in the diffusive gel, 6) study the selectivity of the tested resins gels, 7) the accumulated metal amount is well below the capacity of the binding gel, 8) fast kinetics of the resins gels.

Agarose diffusive gel (AGA) (1.5% agarose) was chosen for lower interaction with PGEs and Hg, adequate blank values and linear response (R2 = 0.99) in function of the time were obtained for the new resins gels and diffusion coefficients could be determined. An aqua regia and thiourea in hydrogen chloride elution methods gave a recovery for PGEs and Hg over 90% and 80% for the R20 and R14 resins gels, respectively. The selectivity test showed these two resins have higher selectivity to PGE and Hg than other trace elements even though they are at very high concentration level and the analysis of PGEs and Hg by sector field ICP-MS optimized. The new resin gels showed capability of accumulation concentration of PGEs and Hg of each hundred times higher than their reported concentrations in the aquatic environments.

Preliminary deployments in the Zenne River and UZ hospital effluent, Brussels, Belgium, showed that Pt, Pd, Rh and Hg can be quantified by the DGT technique using both evaluated resins in fresh water.

Keywords: DGT; PGEs; Hg; SF ICP-MS; diffusive coefficient; surface water; speciation