REPORT OF A MEMBER OF DISSERTATION COUNCIL

The dissertation of *Ibrahem Mohamed Abd Allah Mohamed Abd Elmoaty* on the topic: 'Spatio-temporal variability in Oil Spill Trajectories and Composition in the Gulf of Suez' submitted for the degree of Candidate of Geographical Science in a scientific specialization: 1.6.17. Oceanology

The relevance of this work:

Accidents of oil spills are one of the major fatal events that can happen in the marine environment. The negative impact of such spills does not only affect the marine habitats but also affect coastlines, coastal structures, and investments, which in turn is translated to economical disasters. Expanding knowledge about the physical processes a spill may have once in water and following its trajectory to determine to which extent it may expand is vital and crucial to construct a defense pan and make a quick decision to protect the environment. One of the best tools to achieve the goal is the use of numerical modelling. Luckily, various types of specified models were developed, tested and in use to get oil spills and their behaviour simulated. The present study focused on the use of two well-developed models: GNOME and ADIOS2; in order to simulate the trajectory and changes in the structure of oil spilled in 3 different locations within the Gulf of Suez of Egypt. The Gulf is an important Egyptian water body, which hosts various anthropogenic activities (oil industry, international trade, tourism), in addition to a rich marine environment of corals and fish habitat. Due to its location and use, the Gulf is exposed to the danger of oil spills from the ships passing through the Suez Canal. It is important to investigate the potential fate of such oils on the marine environment as it, by the end, affects the various activities on coasts. This study applies the GNOME and ADIOS2 numerical models to simulate the behaviour of hypothetical oil spills in 3 different locations within the Gulf of Suez, namely: Hurgahda, Ain Sukhna and Southern entrance of the Suez Canal. With different scenarios of changing driving forces, mainly surface currents and winds, the two models have proved to be effective tools to simulate both the trajectories and the physical processes of the investigated oil spills. The released oil in each of the 3 locations was 1000 metric tons of Arabian Light Crude oil.

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In Hurghada, two accidental release of oil was simulated one in winter (February) and another in summer (August) at 50 km north to Hurghada City. In each case, the simulated scenario spanned for 108 hrs. The pathway of oil spill in addition to the weathering processes were figured out and affected areas were specified. The effect of surface currents and blowing wind was significant.

Also, in Ain Sukhna, two accidental release of oil was simulated one in winter (February) and another in summer (August) at 5 km away from Ain Sukhna Port for 72 hrs of simulation. This trial highlighted the greater effect of northerly wind on the track of oil spill and how this may affect the work of the rescue team.

Lastly, 4 scenarios were set to simulate a winter (February) case of oil leakage at the southern entry of the Suez Canal, north to the Gulf of Suez. These scenarios comprised variable current status with various blowing winds: various, NW, N and NE. each case was introduced to show the pathway of the released oil spill and to investigate the weathering processes. This case showed that the emulsification process in the area of investigation is of a special importance, and that the wind has the greater impact on the released oil trajectory

The dissertation scientific novelty was in the first use of two experienced and well-tested numerical models: GNOME and ADIOS2 to simulate the trajectories and physical processes of oil spills in 3 distinctive marine areas in the Gulf of Suez of Egypt: Hurghada, Ain Sukhna and Southern entrance of the Suez Canal, which are of significant importance for the Egyptian economy. The use of such models will undoubtedly improve the ability to deal with any oil spill accident in a well-managed way to minimize the negative impact such spills have on the marine environment, and in turn, on the economy.

The practical significance of the dissertation:

The study provides an effective tool, oil spill modelling, to simulate the trajectory and weathering processes of leaked oil spills upon any accident in the important water body of the Gulf of Suez. This is vital and crucial to evaluate the fate of such spills and to make quick decisions based on actual (real) data and environmental conditions. Hence, risk assessment and environmental protection procedures can be set and successfully achieved.

The dissertation consists of five chapters in addition to an introduction. It ends with a conclusion section followed by a list of figures (40 figures) and a list of tables (14 tables) and 245 references. A brief of the introduction and the five chapters is given below:

Introduction: The research topic, its relevance and the research question of the present work are given in the introduction. The danger of the oil spill accidents and the associated weathering processes are introduced. Also, a brief on the different numerical models used to simulate oil spill trajectories and behaviour is given, with a focus on the two applied numerical models in the study: GNOME and ADIOS2. The introduction also highlights the aim of the present work and its objectives, showing its novelty and contribution to knowledge. The introduction ends with the list of publications (3 papers), conference presentations (2), the personal contribution of the candidate, and the thesis structure.

Chapter 1 Overview of the behavior of marine oil spill

In this chapter, the candidate gives the meaning of marine oil spills, and shows how the development in the oil industry and maritime transportation have increased the risk of oil leakage to the marine environment, especially that the oil is transported worldwide mainly via maritime routes. The major accidents of oil seepage in different marine regions are introduced, and main causes behind are discussed. The candidate also highlights the impact of such spills on the marine environment, coastal structures, oil industry, maritime transportation, which by the end is translated to impacts on the economy. Moreover, the chapter highlights the weathering processes which change the behaviour and structure of oil spills once released to water: evaporation, dissolution, emulsification, dispersion, spreading, drifting, photo-oxidation, biodegradation and sedimentation. The importance of applying numerical models and the different developed models to simulate oil spill trajectories and behavior are given, with results from some previous cases introduced.

Chapter 2 Methodology and Data Used

The area of investigation (Gulf of Suez) and results from previous simulation processes within the Egyptian territory are given in this chapter. The mathematical and operational structures of the two applied models: GNOME (Trajectory) and ADIOS2 (Weathering processes) in the present work are given in details. The model formulation together with the data inputs (coastline configuration, wind data, surface currents, spill volume and oil thickness) of the three considered

regions within the Gulf of Suez: Hurghada, Ain Sukhna and Southern entry of the Suez Canal, are also given in details in this chapter.

Chapter 3 Modeling oil spill trajectory and fate off Hurghada city

This chapter presents the results of the simulation process of an oil spill released at 50 km north to Hurghada city at two different conditions: Winter (February) and summer (August). The seepage is of 1000 metric tons of Arabian Light Crude oil. In the winter case, the NW wind had an obvious effect on the track of the oil spill. After 42 hrs (out of 108 hrs) of simulation, the coastlines of Jubal and Shadwan Islands received oil spills. In the summer case, the NE wind had the greater effect on the track of the oil spill, which reached Ashrafi Island, Geissum and Tawila Island after 21 hrs from the simulation. These trajectories were obtained from the GNOME model. Furthermore, the ADIOS2 model was applied to simulate the weathering processes (evaporation, dispersion, beaching and floating) in the two cases. Results revealed that the in both winter and summer, the evaporation process counted for 27% loss of the spilled oil and that the released Arabian Light Crude oil had a moderate dispersion rate of 1.3%. the candidate concluded that the predicted overall trajectory of the leak should be sufficient to deploy emergency reaction measures immediately.

Chapter 4 Simulation of oil spill movement and fate off Ain Sukhna port

This chapter presents the simulation process of trajectory and weathering processes of an oil spill of 1000 metric tons of Arabian Light Crude oil leaked from a tanker accident at 5 km from the Ain Sukhna port. GNOME model was used to track the oil spill and ADIOS2 model was applied to get information about weathering processes in two scenarios, the first of which is during winter (February) and the second is during summer (July). Winds, sea currents and seawater temperature were considered as drivers and affecting environmental parameters. In February, the oil beached at Ras Abu Darag, 22.7 km from the spill location. About 29.7 metric tons of the spilled oil settled on the shoreline after 18 hours, covering approximately 14.2 km of the western shoreline of the Gulf of Suez. In the meanwhile, 709 metric tons floated southeastward until the simulation ended. In July, the spill moved southwestward, and after 21 hours, about 705 metric tons of oil covered a distance of 10 km along the western coast of the Gulf of Suez at a distance of approximately 10.5 km from the spill location. Results revealed that the oil reaches the shore faster during summer affected by the northeasterly winds. As for the weather processes, the

ADIOS2 outputs revealed that the rate of evaporation and emulsification was high, and the natural dispersion was modest in the two scenarios of simulation. Also, weathering processes were affected by the seawater temperature and kinetic turbulence of seawater.

Chapter 5 Modeling the path and behavior of oil spill at the southern entrance of the Suez Canal

This chapter presents the simulation process of both trajectory and weather processes of an oil spill in the Suez Bay at the southern entrance of the important waterway of the Suez Canal. The hypothetical spill takes place at 2 km from the southern entrance of the Canal. A winter-time (February) accident was supposed to happen resulting in seepage of 1000 metric tons of Arabian Light Crude oil. The track and behavioral changes of the spilled oil were investigated in four different scenarios each of which had its own oceanographic and meteorological conditions. In the four scenarios the sea currents were considered as 'variable', while the meteorological conditions variated in the blowing wind directions, being: (1) variable, (2) NW of constant 4 m/s speed, N of constant 4 m/s speed and NNE of constant 4 m/s speed. The GNOME model outputs revealed that the wind effect was obvious on the tracked oil spill and greatly affected its pathway and time to reach the shoreline. According to the ADIOS2 results, in the 4 scenarios, almost ¼ the spilled oil evaporated and more than ⅔ of the oil emulsified.

Comments and Recommendation

1. Throughout the manuscript punctuation, in addition to some sentences and words need revision and re-writing.
2. Page 7. How can shipping oil have environmental benefits?
3. Page 21. In the author's opinion why these data may not be available? Any suggestion to overcome this problem?
4. Page 21. How does the Coriolis force have a minor effect although it greatly affects sea currents especially surface ones.
5. Page 22. Please, explain Figure 7.1. What is the difference between the two diagrams?
6. Page 39. Figure 2.3 needs to be in a higher resolution to be well-read.
7. Page 41. Mona 2021 [61] must be changed to Hussein 2021 [61]
8. Page 41. Huynh et al. 2021 [46]. This reference deals with the Safer tanker, which has no relation to the Gulf of Suez/Egypt. It is better to move this to the global literature review.

9. All stated equations in chapter 2 need references to be mentioned.
10. Page 49. Can the direct proportion sign in Equation 2.8 be replaced with "= Constant * Equation"? If so what should this constant represent, and with which value/range of values?
11. Page 52. Justify the choice of "covering the northern portion of the Red Sea, including the gulfs of Suez and Aqaba" in Figure 2.7, although the area of interest is the GoS.
12. Page 56. The given wind rose (Fig. 3.3) shows WNW, NW and N directions with almost no NNE direction! Also, 5.4 miles per hour should be given in SI unit.
13. In the hypothetical cases of Hurghada and Ain Sukhna, it is preferable to draw the wind roses of the two months of interest.
14. Page 69. Nominate wind as known by direction from which it blows. So, the dominant wind in the area is NW-N-NNE instead of "The wind is shown to move mostly in SW-SE directions".
15. Page 70. Change "August 7th" to February 10th.
16. Page 71. The author mentioned: "After 42 hours, at 6:00 pm, on February 9th, 2020,…". It is supposed that the simulation starts on February 10$^{th!}$
17. Page 79. Why did the author consider only a winter time case?
18. Page 82. Change 'Wave' in Table 5.1 to 'Wind'.
19. What does the author mean by 'variable seawater current'? This must be explained in 1-2 sentences within the text.
20. Page 84. The author needs to justify this ESE direction in scenario#2.
21. In the case of the southern entrance of the Suez Canal: is there any consideration of the tidal effect on the track of the spilled oil? Can the tidal out-of-phase between the two tips of the Suez Canal affect this case?
22. Page 91. The author mentioned that his results are in agreement with those of Pradhan et al. in the Bay of Bengal, but unfortunately without any justification of this agreement but the wind direction. In the case of the Bengal way the N wind pushed the spill to move SW, i.e. the track is affected by the Coriolis force!
23. The given summary in Page 92 misses any hint on Scenario#2.
24. Some references need to be re-written adequately.

25. In general, is there any possibility to run oil-spill model with real time data feed, i.e. to change the running/driving conditions during the situation itself?

These comments and remark does not affect the overall positive feedback on the submitted thesis.

The dissertation of ***Ibrahem Mohamed Abd Allah Mohamed Abd Elmoaty*** on the topic: 'Spatio-temporal variability in Oil Spill Trajectories and Composition in the Gulf of Suez' **meets** the basic requirements established 19.11.2021 by order 11181/1 "On the procedure for awarding the academic degrees at St. Petersburg State University". The applicant ***Ibrahem Mohamed Abd Allah Mohamed Abd Elmoaty*** **deserves** to be awarded the academic degree of Candidate of Geographical Science in a scientific specialization: 1.6.17. Oceanology.

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