



Large choked lagoon as a barrier for river–sea flux of dissolved pollutants: Case study of the Azov Sea and the Black Sea

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ABSTRACT

The Don River is among the largest rivers in the Eastern Europe and is heavily polluted. This river inflows into small and semi-isolated Sea of Azov, which is connected with the Black Sea by a narrow strait. Generally, the Sea of Azov is a large choked lagoon, which serves as a barrier for river-borne constituents. Using numerical modeling, we reveal that presence of the choked lagoon significantly slows down the estuary-seawater flux of dissolved pollutants and slackens its discharge-induced seasonal variability. In particular, the Sea of Azov delays the 5 % and 95 % of the total flux of riverine pollution to the Black Sea by 9 and 36 months, respectively. The obtained results are important for assessment the influence of background and emergency pollution accidents at the Don River on water quality in the study region. Moreover, these results could be applied to many other choked lagoons in the World Ocean.

1. Introduction

A significant part of the global land-ocean fluxes of suspended and dissolved matter including anthropogenic pollution is provided by river discharge (Milliman and Farnsworth, 2011, 2013; Wagner et al., 2014; Osadchiev et al., 2016, 2019; Lebreton et al., 2017; Dinç et al., 2021). Certain processes in river estuaries as commonly referred as biogeochemical barriers strongly modify these fluxes (Lisitsyn, 1994; Telesh and Khlebovich, 2010; Regnier et al., 2013; Osadchiev et al., 2020a). Choked lagoons, i.e., semi-enclosed estuaries, which connect with open sea through a narrow strait or straights, are among the most efficient biogeochemical barriers due to abrupt changes in flow regime and external forcing conditions at the river-estuary-sea continuum typical for these water bodies (Kjerfve, 1994). Therefore, limited water exchange between choked lagoons and open ocean forms large thermohaline gradients at this interface and significantly affects the fate of river-borne suspended and dissolved substances, including anthropogenic pollutants (Nichols and Boon, 1994; Burrage et al., 2008a; Osadchiev, 2017; Brito et al., 2018; Zavialov et al., 2020, 2021; Gordey and Osadchiev, 2022).

The main motivation of this study is to understand how the presence of a choked lagoon affects a flux of river-borne dissolved pollutants at the river-estuary-sea continuum. Many previous studies were focused on water exchange between two large bodies of water through a narrow strait and its influence on local thermohaline structure and frontal zones (e.g., Beranger et al., 2005; Burrage et al., 2008b; Soto-Navarro et al., 2015; Falina et al., 2017; Sozer and Ozsoy, 2017; Osadchiev et al., 2020b; Lemos et al., 2022). Another large group of studies considered spreading and transformation of river-borne dissolved constituents at different estuarine systems (e.g., Mannino and Harvey, 2000; Zhang et al., 2002; Wen et al., 2008; Liu et al., 2014; Barletta et al., 2019; Raymond et al., 2000), however, we are not aware of any work that addressed these processes for a choked lagoon. The related study requires estimation of residence time of riverine pollutants in a choked lagoon i.e., the periods from their discharge from a river until their outflow to the open. The analysis of long-term fluxes and average residence time of pollutants reveals to what extent a choked lagoon slows down the continuous inflow of background riverine pollution to open sea. The analysis of short-term fluxes and minimal residence time of pollutants reveals how fast the signal of an abrupt emergency pollution

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accident in a river could reach open sea. Both questions are of the major practical importance for many estuarine systems in the World.

In the present work, we consider the Sea of Azov as a choked lagoon, which is connected by a narrow and shallow Kerch Strait with the Black Sea, and study the fate of river-borne constituents at this river-estuary-sea continuum (Fig. 1). The Sea of Azov is a shallow (average depth of 8 m) and brackish (salinity range is 0–12 psu) water body located in the Eastern Europe (Ilyin et al., 2009; Stanev et al., 2017; Zavialov et al., 2020). The Sea of Azov receives large continental discharge, which annual volume varies from 20 to 54 km³, while the total volume of the Sea of Azov is estimated at 290 km³ (Ilyin et al., 2009; Zavialov et al., 2020). Almost all river runoff to the sea is provided by two large rivers, namely, the Don River (up to 70 % of total river runoff) and the Kuban River (Ilyin et al., 2009; Zavialov et al., 2020). The Don River is among the largest rivers in the Eastern Europe, it drain 425,000 km² of densely populated areas, and, therefore, it is heavily polluted (Zhulidov et al., 2003; Nikanorov and Khoruzhaya, 2012; Kuznetsov and Fedorov, 2014; Mikhailenko et al., 2018; Dudnikova et al., 2022). As a result, spreading and transformation of river discharge in the Sea of Azov and its subsequent propagation to the northeastern part of the Black Sea strongly affects transport of pollutants and local water quality (Lomakin et al., 2006; Aleskerova et al., 2017; Zavialov et al., 2018, 2020, 2021; Nemirovskaya et al., 2022).

Generally, the major part of marine pollution in the Azov and Black seas is originated from rivers and it is a problem of great importance due to intense economical and recreational activity in the region (BSC, 2007). During the recent years, many works addressed plastic litter (Berov and Klayn, 2020; Korshenko et al., 2020; D'Hont et al., 2021; Harris et al., 2021), floating marine litter (Stanev and Ricker, 2019; Miladinova et al., 2020; González-Fernández et al., 2022), coastal sources of marine litter (Chuturkova and Simeonova, 2021) in the Black Sea. On the other hand, works addressing river-borne dissolved pollution in the Black Sea are still rare (Dinç et al., 2021), and we are not aware of any work that focuses on the transformation of river-borne dissolved pollution in the Sea of Azov. Moreover, the modeling studies, which addressed spreading of marine pollution in the Black Sea, did not resolve the shallow Sea of Azov and parameterized the freshwater flux from the Sea of Azov to the Black Sea by a boundary condition at the Kerch strait (Korshenko et al., 2020; Stanev and Ricker, 2019; Miladinova et al., 2020).

In this study, we use numerical modeling to reconstruct the spreading of dissolved pollutants, which are discharged from the Don River to the Sea of Azov and further to the Black Sea. We aim to understand how the Sea of Azov affects the short-term and long-term fluxes

of dissolved pollutants from the Don River to the open part of the Black Sea. Based on numerical modeling, we reconstruct statistical characteristics of the residence time of riverine tracers in the Sea of Azov. We reveal (1) to what extent the Sea of Azov slows down the continuous inflow of background pollution from the Don River to the Black Sea and (2) how fast the signal of an abrupt emergency pollution accident in the Don River could reach the Black Sea.

The paper is organized as follows. Information about the numerical model, brief description of its regional setting, and layout of the numerical experiments are provided in Section 2. Section 3 describes the numerical simulation results, analyzes residence time of model tracers in the Azov and Black seas, and discusses the role of the Sea of Azov in slackening the river-estuary-sea fluxes of dissolved pollutants on short-term and long-term time scales. The summary and conclusions are presented in Section 4.

2. Numerical model

In this study, we use a regional realization BSAS12 (Black Sea Azov Sea 1/12°) of the Azov and Black seas of the ocean circulation model NEMO (Nucleus European Model of Ocean) (Madec and the NEMO Team, 2016), which was previously described and validated in our recent study (Zavialov et al., 2020). Regional model BSAS12 simulated ocean circulation in the Black Sea and the Sea of Azov with a regular numerical grid and horizontal resolution of 1/12° (~6.75 km). In vertical dimension, it has 59 vertical z-levels with partial step and a fine vertical resolution of the upper sea layer with vertical grid size from 0.5 to 1 m for the first 10 m (Barnier et al., 2006). The model is forced by the ERA-Interim atmospheric reanalysis fields, it has an open boundary at the Bosphorus Strait. River runoff in the Sea of Azov is represented by the Don and Kuban rivers according to daily gauge data acquired from the most downstream Razdorskaya and Temryuk gauge stations, respectively. The detailed validation of the BSAS12 model was provided in Zavialov et al. (2020) in Supplementary materials. The model correctly simulates the main features of the Black Sea circulation including the Rim Current, quasi-stationary cyclonic gyres at the central divergence zone, and quasi-stationary anticyclonic gyres at the periphery of the Rim Current (near Batumi, Sukhum, Sevastopol, etc.) (Stanev, 1990; Stanev et al., 1995) (Fig. 2). Also, the model adequately reproduces the anticyclonic circulation in the Sea of Azov (albeit less prominent and stable than in the Black Sea) as well as the complex water exchanges between the Azov and Black seas through the Kerch Strait, which was the case of our recent study (Zavialov et al., 2020).

In order to estimate the residence time of the riverine tracers in the

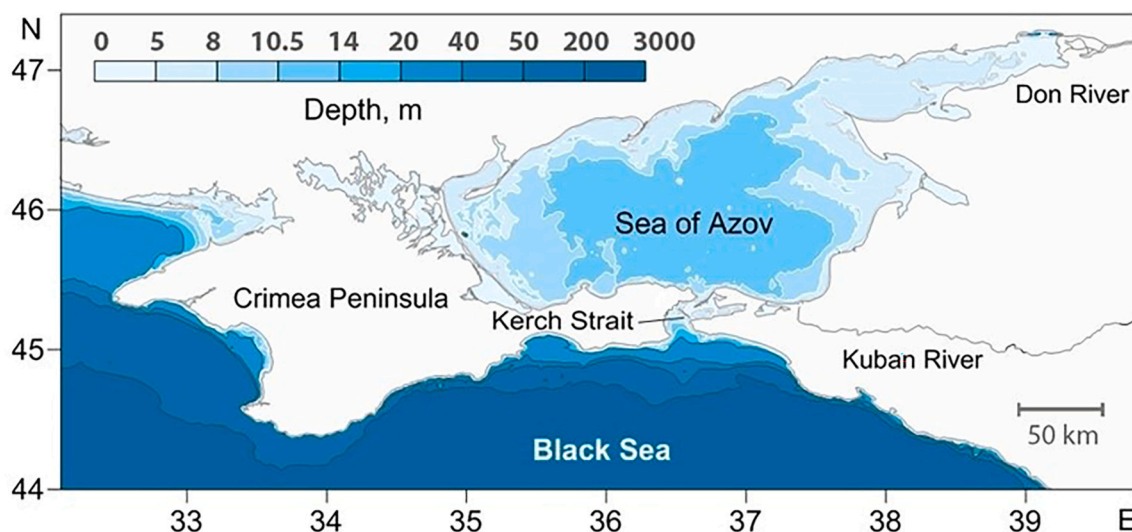


Fig. 1. Bathymetry of the Sea of Azov and the northern part of the Black Sea and locations of the Don and Kuban river mouths.

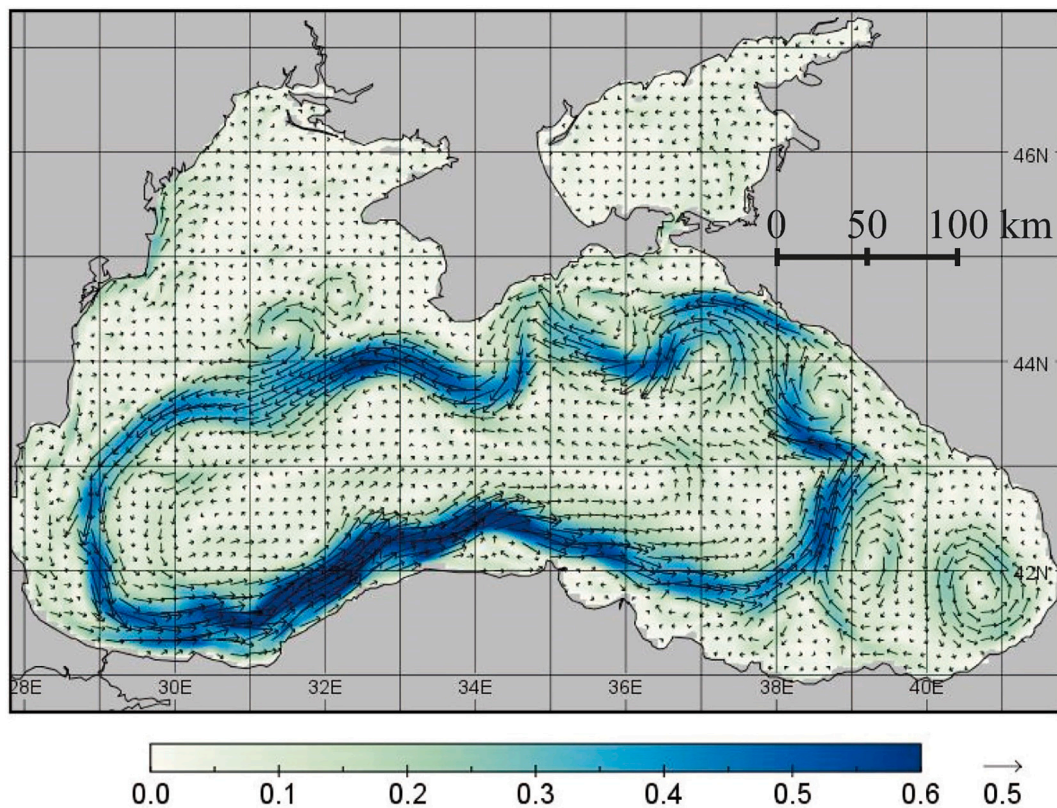


Fig. 2. A snapshot of sea surface velocity at 23 January 2002 simulated by BSAS12, which demonstrates the main features of the Black Sea circulation.

Sea of Azov, we conducted a numerical experiment with passive tracers. The purpose of the experiment is to evaluate the response of the Azov and Black seas to the release of pollutants from the Don River mouth. The outline of the numerical experiment is as follows:

- First stage: a “cold start” is initiated (the climatic salinity and temperature fields and a zero velocity field) with a spin-up period of 2 years in order to obtain the typical water circulation for the study area. The initial temperature and salinity fields of the Azov and Black seas are obtained from the climatological data given in Goptarev et al. (1991) and Belokopytov (2018).
- Second stage: a source of passive tracers is initiated at the Don River mouth (red box in Fig. 3) simulating the inflow of stable river-borne dissolved pollutants to the Sea of Azov. The tracers are introduced to the specified area during the next 1 year of simulation.
- Third stage: release of new tracers into the model domain is stopped and the residence time of tracers in the Sea of Azov and the Black Sea is registered. The third stage is the longest and takes 16 years.

We conducted numerical simulation from 1 January 1999 to 31 December 2017. The results of the numerical simulation are 3D fields of system parameters (salinity, temperature, velocity, sea surface height, and concentration of tracers) saved as daily averages. Lagrangian passive tracers are used in the experiment to simulate the advection of dissolved pollutants. The dynamics of the passive tracers are governed by the same advection, mixing and diffusion schemes as for salinity and temperature. Passive tracers do not affect water circulation, as their concentration do not affect water density. Conservation of mass holds during the simulation with account of the addition of tracers from the source and the extraction of tracers from the sink. During the period of tracer release, their concentration in the source (river mouth) is prescribed equal to 1 (Fig. 3). From the daily averaged output, we calculated monthly and annual means of concentration of tracers and spatial

averages over the Black Sea and the Sea of Azov individually, as well as over the entire domain (note, concentration of tracers is a dimensionless quantity, i.e., it is measured in dimensionless units). Since the model has an open boundary at the Bosphorus Strait, we introduced a sink of tracers at the related grid points, which represents advection of pollutants out of the Black Sea through the strait.

3. Results

3.1. Horizontal and vertical distributions of tracers

Distributions of concentrations of tracers in the surface layer of the Sea of Azov during four different time periods are shown in Fig. 3. Tracers are initially released to the northeastern part of the Sea of Azov. During the first year, they are advected mainly along the northern shoreline, which is manifested by the highest concentrations (>0.05) (Fig. 3a). Concentrations in the rest of the sea do not exceed 0.01. During the second year, i.e., shortly after the termination of tracer release, the largest concentrations (>0.05) remain in the northeastern part of the sea, however, similar concentrations are observed in the western part of the sea (Fig. 3b). During the next two years, concentration of tracers in the Sea of Azov becomes more homogenous. Concentration of tracers in the northeastern part of the sea steadily decreases due to their dilution and advection by the inflowing “clean” river discharge (Fig. 3c). As a result, this area becomes the less contaminated in the sea (0.02–0.03). Concentration in the western part of the sea, on the opposite, remains the largest in the sea (0.035–0.04). This feature indicates accumulation of river-borne pollutants in this area due to its certain isolation from the general circulation flow from the Don River mouth towards the Kerch Strait. 16 years after the start of the tracers release, their concentration dramatically (by one order of magnitude) drops in the whole sea (<0.004) (Fig. 3d). As a result, the majority of tracers are removed from the Sea of Azov by the end of the model experiment. The northeastern

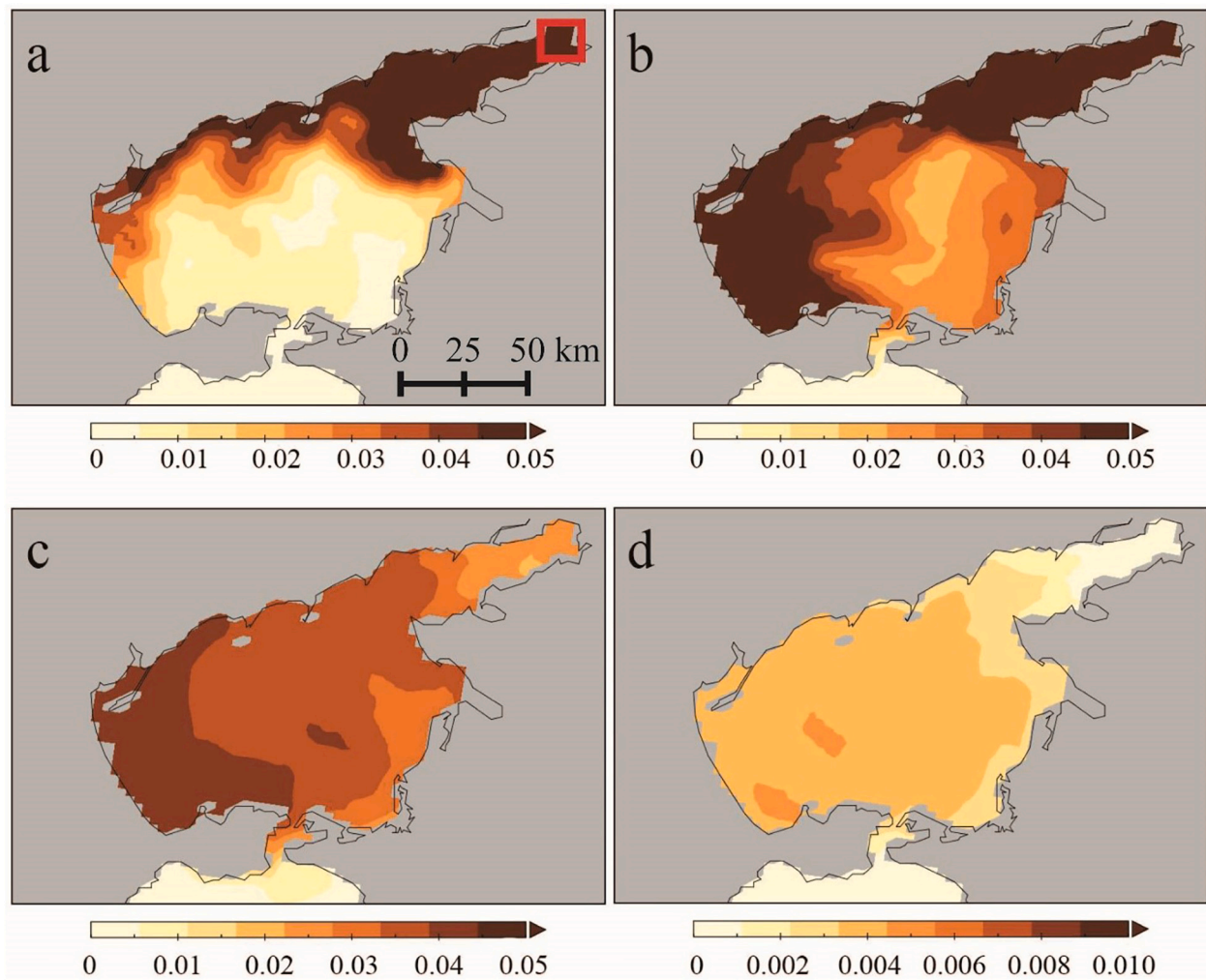


Fig. 3. Monthly averaged surface distributions of tracer concentrations (a) 12 months, (b) 22 months, (c) 50 months, (d) 190 months after the experiment start. The red box in the panel (a) represents the source of passive tracers. Note that the scale in the panel (d) is 5 times smaller than in the panels (a)–(c). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

part of the sea near the Don River mouth remains the least contaminated area (<0.001).

Note that the observed reduction of concentration of pollutants near the freshwater source in the northeastern part of the sea is an artifact of the numerical experiment. It is caused by abrupt stop of tracer release at the third stage of the experiment, which is motivated by accurate assessment of residence time of tracers in the Sea of Azov. Certainly, it is not the case of background pollution in real estuarine systems; however, it could be attributed to emergency and short-term pollution accidents in rivers.

Distributions of concentrations of tracers in the surface layer of the Black Sea during four different time periods are shown in Fig. 4. The tracers are initially advected to the Black Sea from the Kerch Strait and then are transported along the continental slope in a counterclockwise direction by the Rim Current. As a result, 4 years after the tracers release start, the largest tracer concentrations are registered near the Kerch Strait (>0.0006) and in the northwestern and western parts of the sea (0.0004 – 0.0006) (Fig. 4a). Note that these concentrations are two order of magnitude smaller than those observed at the same time in the Sea of Azov (Fig. 3c). During the next two years, concentrations of tracers steadily increase in the whole sea (Fig. 4b). However, the area adjacent to the Kerch Strait (>0.0006) and the northwestern and western parts of the sea (0.0005 – 0.0006) remain the most contaminated. The lowest concentrations of tracers (<0.00035) are observed in two divergence

zones the central part of the sea. During the next 5 years concentrations in these divergence zones steadily increase to 0.00035 – 0.0004 , while concentrations in all other areas steadily decrease (Fig. 4c). Finally, 14 years after the tracers release started, the concentration of tracers becomes relatively homogenous (0.0004 – 0.00045) in the Black Sea (Fig. 4d). The northwestern part of the Black Sea contains large volume of tracers during the first part of the experiment, because the tracers are more slowly entrained to the Rim Current from this semi-isolated area. However, on the long-term period the surface layer in this area is significantly diluted by the discharges from the Danube, Dnieper and Dniester rivers, which do not contain pollution tracers in the simulation. As a result, the northwestern part of the Black Sea becomes the least contaminated area by the end of the numerical experiment.

In order to assess vertical advection of tracers, we analyzed their vertical distributions in the study area during the numerical experiment. For this purpose, we averaged vertical distribution of tracer concentrations over the whole sea basins for both the Sea of Azov (Fig. 5a) and the Black Sea (Fig. 5b). The shallow Sea of Azov with the average depth of 8 m is well ventilated (Ilyin et al., 2009). Therefore, the observed vertical distribution of tracers is homogenous except first 3 years of simulation with maximal concentrations in the surface layer (Fig. 5a). Vertical distribution of tracers in the Black Sea is significantly different than that in the Sea of Azov (Fig. 5b). The strong halocline at the depths of 90–120 m, which is among the most important features of vertical

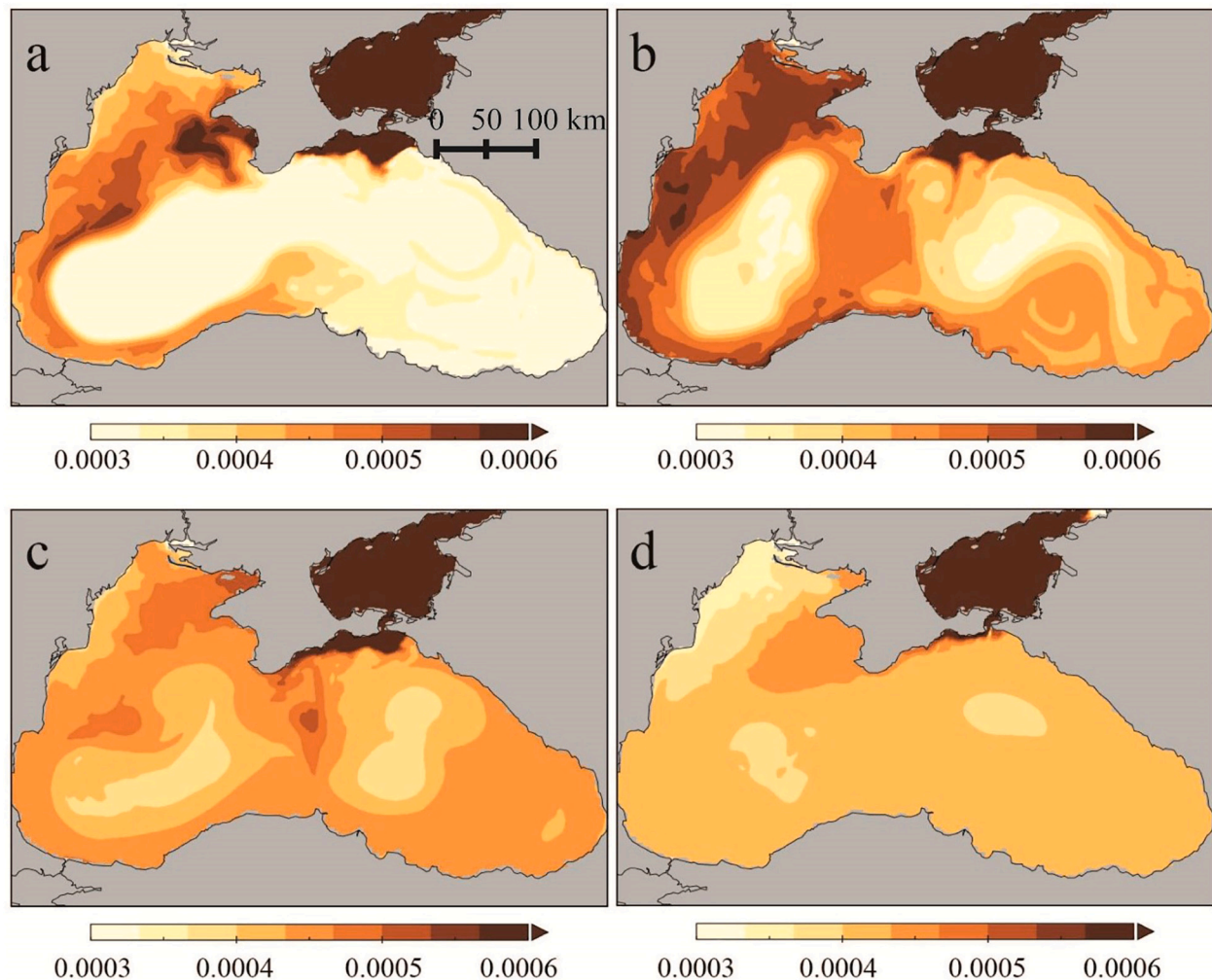


Fig. 4. Monthly averaged surface distributions of tracer concentrations (a) 4 years, (b) 6 years, (c) 11 years, (d) 14 years after the experiment start.

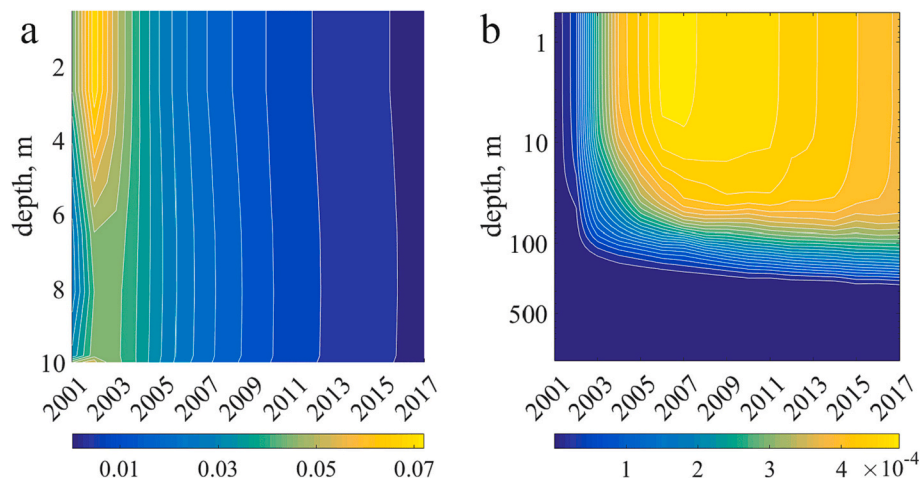


Fig. 5. Basin averaged vertical distributions of tracer concentrations in (a) the Sea of Azov, (b) the Black Sea during the numerical experiment. Note, that the depth in panel (b) is given in a logarithmic scale.

thermohaline structure of the Black Sea (Stanev, 1990; Stanev et al., 1995), prevents penetration of tracers to the deep part of the sea. Maximal concentration of tracers is registered in the surface layer during 5–6 years after the experiment start due to their inflow from the shallow Sea of Azov. Therefore, the time lag between maximal surface

concentrations in the Azov and Black seas is equal to 4–5 years.

3.2. Residence time of tracers

The performed numerical experiment provided the background for

understanding how the Sea of Azov affects the short-term and long-term fluxes of dissolved pollutants from the Don River to the open part of the Black Sea. First, we analyzed the basin-averaged concentrations of tracers for the Sea of Azov (Fig. 6a), the Black Sea (Fig. 6b) and both seas together (Fig. 6c). During the second stage of experiment, i.e., the first year of the numerical experiment when the tracers are released, the basin-averaged concentration of tracers in the Sea of Azov steadily increases. By the termination of tracer release, their concentration in the Sea of Azov reaches its maximum of 0.07 (Fig. 6a). Note, that during the first year there is almost no advection of tracers from the Sea of Azov to the Black Sea, which is illustrated by almost zero concentration in the Black Sea (Fig. 6b). Then during the next year, the concentrations in both seas remain stable because of very low advection of tracers from the Sea of Azov to the Black Sea.

During the third year of numerical experiment, the flux of tracers from the Sea of Azov to the Black Sea abruptly intensifies, which results in decrease/increase of tracer concentrations in the Azov/Black seas (Fig. 6a, b). By this time, the large volume of river-borne constituents finally reached the Kerch Strait area in the Sea of Azov. The concentration of tracers in the Sea of Azov returns to the level of the first month of polluting regime 4 years after the termination of pollution (Fig. 6a). In 11 years, this concentration decreases by 10 times from the peak value. By the end of the numerical experiment, the concentration decreases to 0.0025.

The basin-averaged concentrations of tracers shown in Fig. 6 demonstrates the absence of strong seasonality in the advection of tracers from the Sea of Azov to the Black Sea. The discharge of the Don River to the Sea of Azov and the related inflow of tracers have distinct seasonal variability. However, the presence of the choked morphology of the Sea of Azov hampers this discharge-induced seasonal signal within the estuary. As a result, we do not observe significant seasonal cycle in the flux of dissolved pollutants through the Kerch Strait to the Black Sea.

The observed decrease of tracers concentration in the Sea of Azov could be approximated by an exponential function $f(x) = ae^{bx}$, where $a = 55$, $b = -0.06$. The concentration of tracers in the Black Sea, on the opposite, steadily increases up to 0.0038 (Fig. 6b). Nevertheless, concentration in the Black Sea never reaches the values of that in the Sea of Azov during the numerical experiment. The observed increase of tracers concentration in the Black Sea could be approximated by a logarithmic function $f(x) = a + b \log_{10} x$, where $a = 184$, $b = 155$. In order to analyze the outflow of tracers from the model domain, i.e., advection of tracers from the Black Sea through the Bosphorus Strait, we calculated the concentrations of tracers averaged by both seas (Fig. 6c). The notable advection of tracers off the Black Sea started 6 years after the start of numerical experiment. It was relatively homogenous until the end of the model run and resulted in decrease of tracers' concentration in the model domain from 0.042 to 0.04, i.e., 5 % of all released tracers.

Based on the obtained results, we calculated the residence time of riverine tracers in the Sea of Azov, i.e., the periods from their discharge from the Don River to the Sea of Azov till their outflow to the Black Sea (Fig. 7). Almost one quarter of all tracers released to the Sea of Azov remained there during less than one year. Residence time of more than a half of all tracers did not exceed three years and only 9 % of tracers remained in the Sea of Azov longer than 10 years.

Finally, we calculated minimal/average/maximal residence times $T_{\min}/T_{\text{av}}/T_{\max}$ as the time periods during which 5 %/50 %/95 % of all tracers leave the Sea of Azov (Fig. 8). We presume that these parameters are indicative of the role of the Sea of Azov as the barrier between the Don River and the Black Sea. T_{av} and T_{\max} are equal to 37 and 178 months, respectively. It demonstrates that the Sea of Azov significantly slows down the continuous inflow of background pollution from the Don River to the Black Sea. T_{\min} is equal to 9 month, which is a direct time assessment how fast the signal of an abrupt emergency pollution accident in the river could reach the Black Sea.

4. Summary and conclusions

This study is focused on the influence of a large choked lagoon on

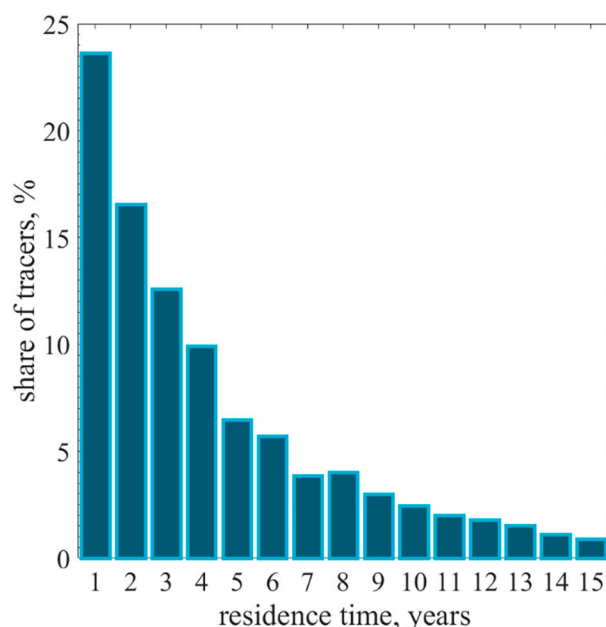


Fig. 7. Annual distribution of residence time of tracers in the Sea of Azov.

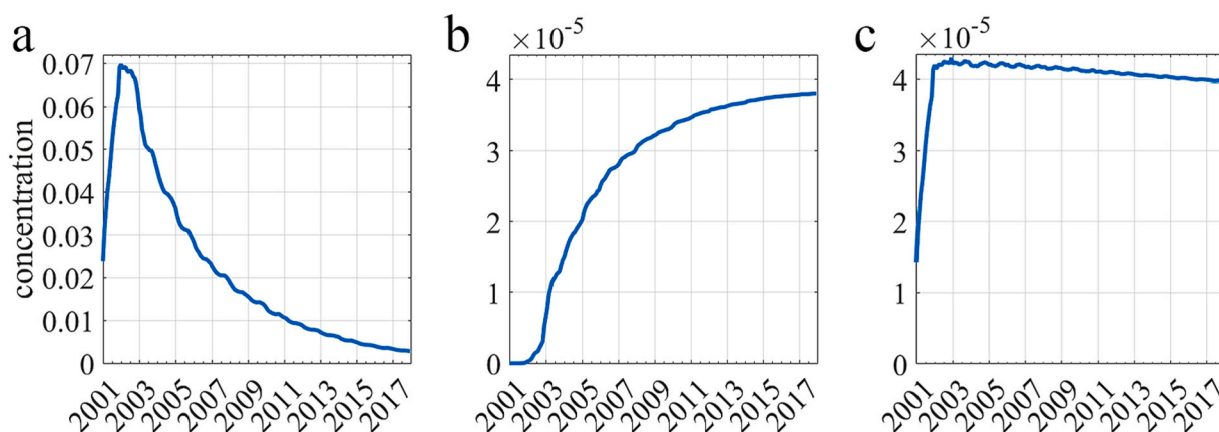


Fig. 6. Basin-averaged concentrations of tracers in (a) the Sea of Azov, (b) the Black Sea, (c) in both seas during the numerical experiment.

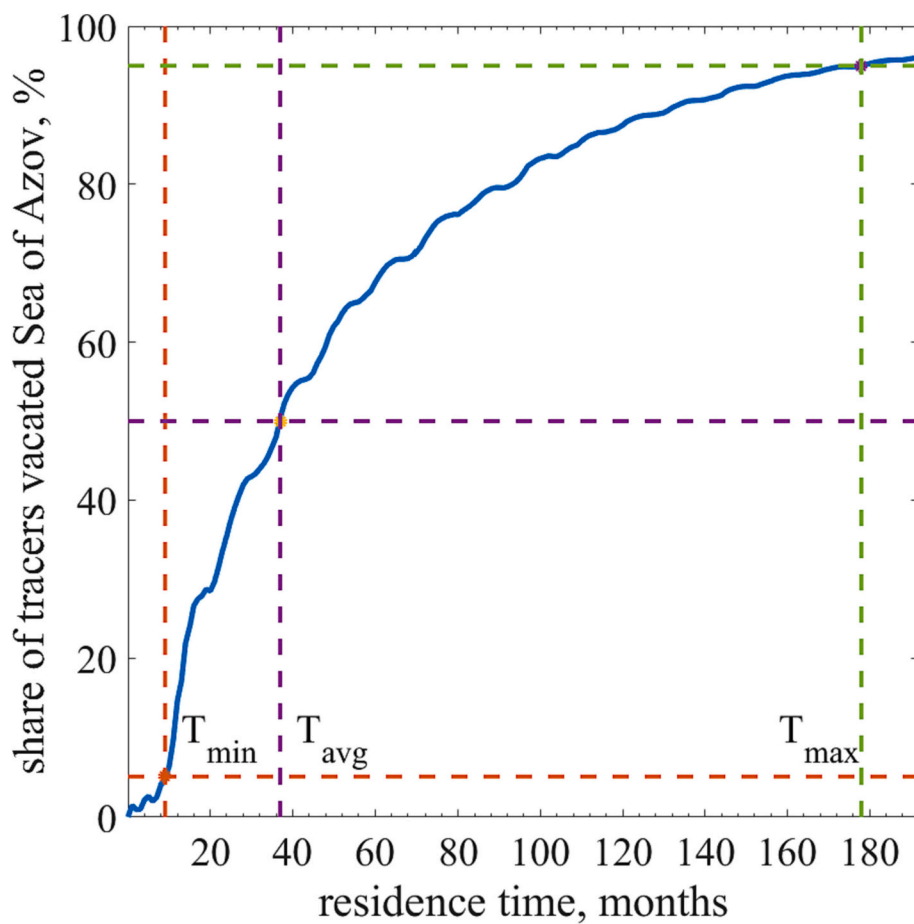


Fig. 8. The share of tracers remaining in the Sea of Azov during the numerical experiment with indication of minimal (red dashed line), average (magenta dashed line), and maximal (green dashed line) residence times. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the fate of river-borne constituents at the river-estuary-sea continuum. We used numerical modeling to reconstruct the transport of dissolved constituents discharged from the Don River to the Sea of Azov and their subsequent outflow to the Black Sea. We demonstrate that the narrow Kerch Strait, which connects the Azov and Black seas, significantly slows down the water exchange rate between these seas. In addition, we reveal that the presence of a choked lagoon slackens discharge-induced seasonal variability in estuary-sea water exchange. The strong seasonal signal of the Don River discharge rate dissipates in the choked lagoon and do not result in seasonality of water exchange through the Kerch Strait. As a result, we do not observe distinct seasonal cycle in the river-sea flux of dissolved pollutants, which is not the case of typical (non-choked) estuaries.

Riverine dissolved pollutants in the Sea of Azov are initially concentrated in the western part of the sea. In the Black Sea, elevated concentrations are observed along the continental slope and at the northern and northwestern shelf, while the divergence areas in the central part of the Sea have the lowest pollution. Strong halocline at the Black Sea prevents penetration of dissolved pollutants below the depths of 150 m, keeping them localized in the upper sea. However, maximal concentrations of pollutants in the Black Sea is two orders of magnitude smaller than those in the Sea of Azov.

Numerical modeling clearly demonstrates that the Sea of Azov plays a role of an effective barrier for the river-sea flux of dissolved pollutants, which is not observed at estuaries with non-choked morphology. In particular, the Sea of Azov delays the inflow of 50 % of volume of the riverine pollution to the Black Sea by 4 years, which represents the average residence time of pollutants in the estuary. This result reveals to

what extent the Sea of Azov slows down the continuous inflow of background pollution from the Don River to the Black Sea. 95 % of the discharged riverine pollution is advected to the Black Sea only after a time lag of 15 years, which can be regarded as a self-cleaning time scale for the Sea of Azov. On the other hand, 5 % of the discharged riverine pollution reaches the Black Sea only in 9 months. This relatively small time lag demonstrates how fast the signal of an abrupt emergency pollution accident at the Don River could reach the Black Sea. Finally, we obtained numerical parameterizations for the fluxes of pollutants through the Kerch and Bosphorus straits, which could be useful for the related numerical studies of riverine pollution in this area.

The Kuban River is the second important source of riverine pollution in the Sea of Azov, albeit it is much smaller than the Don River. The Kuban River inflows to the sea near the Kerch Strait, which is much closer to the Black Sea than the Don River mouth. However, discharge of the Kuban River and the related riverine pollution is entrained by the anticyclonic circulation of the Sea of Azov, therefore, generally it reaches the Kerch Strait and the Black Sea even longer than the discharge and pollution from the Don River. In this case, the southwestern part of the Sea of Azov is the most unfavorable area to be the source of pollution, because it will be very quickly advected to the Black Sea. Nevertheless, this area does not receive land-based pollution due to absence of large rivers and industrial objects.

Future studies are required for better understanding the influence of choked lagoons on fluxes of riverine discharge, dissolved and suspended matter at the river-estuary-sea continuum. First, numerical experiments with idealized choked lagoons could provide new insights how the morphology of the lagoon and the lagoon-sea channel (i.e., volume,

area, depth, shape), as well as external forcing conditions (i.e., river discharge, wind forcing) govern the lagoon-sea exchange processes. These experiments could result in development of dimensionless parameters, which describe these processes. Second, the obtained results for the idealized choked lagoons could be verified and tuned for real choked lagoon in the World Ocean, which have wide variety of morphologic characteristics and external forcing conditions.

CRedit authorship contribution statement

Roman Sedakov: Methodology, Software, Writing - original draft preparation.

Alexander Osadchiev: Conceptualization, Methodology, Writing - original draft preparation.

Bernard Barnier: Methodology, Software, Validation, Writing - reviewing and editing.

Jean-Marc Molines: Software, Validation, Writing - reviewing and editing.

Pedro Colombo: Software, Validation, Writing - reviewing and editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The river discharge data were downloaded from the Federal Service for Hydrometeorology and Environmental Monitoring of Russia (RosHydroMet) repository (<http://gis.vodinfo.ru>). The ERA-Interim atmospheric reanalysis data were downloaded from the European Centre for Medium-Range Weather Forecasts (ECMWF) website (<http://apps.ecmwf.int/datasets/>).

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