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THE BLACK SEA HOT SPOTS METHODOLOGY: GENERAL OVERVIEW AND UA RESULTS

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Purpose. The Black Sea is a transboundary water body and that is why international cooperation is very important for the protection of the Black Sea ecosystem. Land-based pollution sources (LBSs) produce great negative impact on the Black Sea ecosystem and that is why scientists have initiated national and international projects devoted to finding ways for elimination of the pressure caused by land-based pollution sources. ***Methodology*.** The paper describes the Black Sea Hot Spots Methodology and presents results of UA Hot Spots ranking. The HSs Methodology consists of four stages and allows to identify and rank Hot Spots located on the territory of the Black Sea catchment area (200 km coastal zone). The list of criteria contains environmental, socioeconomic, and integrative indices. The Methodology includes an expertise scoring (expert-judgment), but also mathematical methods for estimating the effect of Hot Spots on the environment of the Black Sea. The Methodology is equipped with a Software, which allows to automatically connect to the LBSs/HSs Database and with an additional input of required data/information to pass through all levels of screening of LBSs and identify which of them are Hot Spots as well as to prioritize them for investment planning. ***Originality and results***. The paper presents results of four pilot testings performed in 2014-2015 for Ukraine. The final list of UA Hot Spots contains municipal and industrial WWTPs as well as urban surface run-off. ***Practical value***. The Black Sea Hot Spots Methodology was developed for identification, assessment and prioritization of Hot Spots, located within the Black Sea catchment area. The Methodology was proposed to the Black Sea Commission for adoption and regular use in the region. *References 13, tables 4, no figures.*

Key words: Methodology, Hot Spot, identification, prioritization, Black Sea

МЕТОДИКА РАНЖИРУВАННЯ «ГАРЯЧИХ ТОЧОК» ЧОРНОГО МОРЯ: ЗАГАЛЬНИЙ ОГЛЯД ТА РЕЗУЛЬТАТИ ДЛЯ УКРАЇНИ

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У статті описується розроблена авторами методика ідентифікації і ранжирування «гарячих точок» Чорного моря і приведені результати її пілотного тестування для джерел забруднення, розташованих на території України. Методика розроблялася з метою виявлення джерел забруднення Чорного моря, що потенційно впливають на екосистему Чорного моря, різноманіття, здоров'я людини, економічну стабільність. У розробленій методиці використовується поетапне оцінювання значимості різних джерел забруднення. На початкових етапах для вибору з усієї сукупності джерел забруднення кандидатів у «гарячі точки» застосовуються прості критерії, що не вимагають великої кількості вихідних даних і математичних розрахунків. На заключних етапах для ранжирування і категоризації джерел забруднення поряд із критеріями, заснованими на експертних оцінках, застосовуються також критерії, засновані на математичних розрахунках. У рамках методики розроблена програма, що забезпечує інформаційний зв'язок з базою даних джерел забруднення Чорного моря і виконання всіх необхідних розрахунків. Приведено результати 4-х пілотних тестувань методики для ідентифікації і ранжирування «гарячих точок» України, проведених у 2014-2015 р. В останній версії методики розглядалися не тільки промислові і комунально-побутові скиди зворотних вод у Чорне море, але також і поверхневий стік з урбанізованих територій. Основні відмінності розробленої методики від методик, що застосовувалися раніше: 1) використання критеріїв, заснованих на математичних розрахунках, 2) використання соціально-економічних критеріїв, 3) врахування джерел забруднення, розташованих на відстані до 200 км від моря. Ідентифікація і ранжирування «гарячих точок» Чорного моря за допомогою розробленої методики може

бути використане для планування природоохоронних інвестицій у чорноморському регіоні. Розроблена методика запропонована Чорноморської комісії для адаптації і використання в регіоні.
Ключові слова: методологія, «гарячі точки», ідентифікація, пріоритетизація, Чорне море.

PROBLEM STATEMENT. Black Sea (BS) is a transboundary water body and that is why international cooperation is very important for the protection of the Black Sea ecosystem. International cooperation includes legislation and scientific sector which are closely connected. In 1996 Convention on the Protection of the Black Sea Against Pollution [1]; it sets out the overall objectives and obligations of the contracting Parties (Bulgaria, Georgia, Romania, Russian Federation, Turkey and Ukraine) in Black Sea protection, the actual implementation of each of these is to be done through more detailed and specific Protocols. In 1996, the Bucharest Convention implementation was given a tight time-frame through an ambitious Strategic Action Plan (SAP [2], currently replaced by [3]) and the first regional List of BSHot Spots (HSs) was prepared shortly before [4].

Land-based pollution sources (LBSs) produce great negative impact on the Black Sea ecosystem and that is why scientists have initiated national and international projects devoted to finding ways for elimination of the pressure caused by land-based pollution sources.

In 1996 ten UA Hot Spots were identified using WHO "rapid assessment" methodology [5-7].

During 2013-2015 under the framework of the project "Integrated hotspots management and saving the living Black Sea ecosystem" – HotBlackSea (grant agreement Nr 2.2.1.72761.225 MIS-ETC 2303, Black Sea Cooperation Programme) the Hot Spots Methodology - Guiding harmonization in identification and prioritization of Hot Spots in the Black Sea Region (the Black Sea Hot Spots Methodology or the BS HSs Methodology) was developed [8]. Before starting the project some background work was carried out [4] and in preparation of the BS HSs Methodology, the draft Black Sea Commission HS Methodology was taken as a basis, as well as best available practices in the development of national and regional (Arctic Seas, MEDPOL, DABLAS, HELCOM, OSPAR) methods of identification, evaluation and ranking of point sources of pollution.

Firstly, some words about key term "Hot Spot". In compliance with the regional LBSA Protocol, 2009 [9], Hot Spot means a limited and definable local land area, stretch of water surface or specific aquifer that is subject to excessive pollution and necessitates priority attention in order to prevent or reduce the actual or potential adverse impacts on human health, ecosystems or natural resources and amenities of economic importance.

For the purposes of the BS Ss Methodology, the Hot Spot is considered to mean *point source* on the coast of the Sea, which potentially *affect* human health, ecosystems, biodiversity, sustainability or economy in a significant manner. They are the *main points, where high levels of pollution loads* originating from domestic (municipal) or industrial sources are being *discharged* – so municipal and industrial waste water treatment plants (WWTP). Also *urban surface run-off* from the territory of a city/town/settlement is considered as a Hot Spot no matter through how many discharge collectors it enters the Black Sea or connected river/lake.

The paper presents the Black Sea HSs Methodology [10] and UA results.

Recently the BS HSs Methodology was proposed to the Commission on the Protection of the Black Sea Against Pollution (Black Sea Commission) for adoption and regular use in the region which would ensure the BS coastal states evaluate their LBSs in a harmonised way and would help them improve the national investment planning in BS protection. The final list of prioritized UA Hot Spots was presented to the Ministry of Ecology and Natural resources of Ukraine and regional environmental authorities.

EXPERIMENTAL PART AND RESULTS OBTAINED. The Black Sea Hot Spots Methodology [10] is intended to ensure common approach to identification, assessment and ranking of Hot Spots, located within the Black Sea catchment area and having impact on the state of the Black Sea. HSs Methodology deals mainly with point LBSs as diffuse sources of pollution are poorly studied in the BS region.

Distinctive features of the BS HSs Methodology are the following:

– the HSs Methodology allows to identify and rank Hot Spots located on the territory of the Black Sea catchment area;

– when ranking common criteria for all Black Sea countries were chosen taking into consideration availability of data;

– the list of criteria contains environmental, socioeconomic, and integrative indices;

– the HS Methodology includes an expertise scoring (expert-judgment), but also mathematical methods for estimating the effect of Hot Spots on the environment of the Black Sea;

– to support the use of this HSs Methodology a special database on LBSs was developed; it contains meta data and data on discharges (concentrations and/or loads) of key LBSs;

– the HSs Methodology is equipped with a Software, which allows to automatically connect to the LBS Database [11, 12] and with an additional input of required data/information (which is not part of the LBS Database) to pass through all levels of screening of LBSs and identify which of them are Hot Spots as well as to prioritize them for investment planning.

Thus, the ranked list o HSs is calculated for each Black Sea country by using specific data (statistical and scientific ones); the Black Sea HSs Methodology includes mathematical models as well as expertise scoring. The BS HSs Methodology includes correlation coefficients which allow to take into account specific feature of each country.

To support the use of this Methodology a special database on LBSs/HSs (the Hot Spots Database - HSs DB) was developed [12]. It contains meta data and data on discharges (concentrations and/or loads) of key LBSs

from the Black Sea catchment area. Currently the database contains data and information only on point pollution sources, in future it is planned to include also data on surface run-off. For more information see the Final Project Booklet and the manual on the HSs DB [12].

The Methodology is equipped with a Software (available on the project website after registration), which allows to automatically connect to the LBSs/HSs Database (DB) and with an additional input of required data/information (which is not part of the DB) to pass through all levels of screening of LBSs and identify which of them are Hot Spots as well as to prioritize them for investment planning.

General Algorithm of the Black Sea HSs Methodology.

The Black Sea Hot Spots Methodology includes the following stages of work (Fig.1):

Stage 1 – Compilation of full LBSs List (as full as possible);

Stage 2 – First level screening – selection of Hot Spots candidates using various indicators characterizing waste water pollution;

Stage 3 – Second level screening and first prioritization to identify top Hot Spots. Prioritization is performed on environmental and socio-economic (welfare) criteria;

Stage 4 – Third level screening to verify the prioritization according to more sophisticated criteria and build the final HSs List, which would be eligible to speak about priorities in investments and their schedule (short-, mid-, and long-term), and selection of top priority HSs.

Thus, selection of Hot Spot candidates is conducted on Stage 2 of the HSs Methodology. Assessment and ranking of the Hot Spot Candidates are performed on Stage 3. Final prioritization of the Hot Spots is performed on Stage 4. This prioritization is provided in support of decision-making on investments.

At each of the HSs Methodology stages a number of assessment criteria are used, which require additional data/information input. 'Additional' means such data/information which are not available in the LBSs/HSs Database and are not automatically derived through the HS Methodology Software.

Hot Spots identification and ranking criteria.

At the first stage of the Black Sea Hot Spots Methodology, compilation of meta data and data on key LBSs is carried out. HSs DB was nourished with meta data and data on Black Sea-related land-based sources of pollution (LBSs), which were used to verify and update the Lists of Black Sea Hot Spots in the HBS Project beneficiary countries. The HBS Project HSs Software automatically links to the HSs DB and calculates all criteria enlisted in the HSs Methodology.

At the second stage of the Black Sea Hot Spots Methodology, a list of environmental ranking criteria for the selection of HSs Candidates is proposed. These criteria were chosen based on existing best available practices (e.g. methodologies developed for other seas and by other organizations/projects, as mentioned above) and also taking into account the advice provided by the stakeholders involved in the Methodology development.

Thus, not all sources of pollution should be considered Hot Spots as some of them do not potentially affect human health, ecosystems, biodiversity, sustainability or economy in a significant manner. On this basis at the second stage of the Hot Spots Methodology "First level screening – selection of Hot Spots candidates" it is necessary to include those facilities (municipal and industrial), for which at least one of the key conditions is observed:

– Discharge volume is more than 1000 m^3 / day;

– Absence of sewage treatment plant;

– Discharge pollution in terms of BOD_5 - > 50 t/year for municipal and BOD_5 > 30 t/year for industrial waste waters;

– Discharge pollution in terms of total concentration of trace metals - > 1 mg/dm^3;

– Discharge pollution in terms of total nitrogen - > 20 t/year for municipal and > 5 t/year for industrial waste waters;

– Discharge pollution in terms of total phosphorus - > 6 t/year for municipal and > 2 t/year for industrial waste waters;

Note: Due to the fact that in some BS countries organic nitrogen is not controlled in wastewater, it is proposed to use the sum of inorganic forms of nitrogen (ammonia nitrogen + nitrate nitrogen + nitrite nitrogen) – > 15 t/year for municipal and > 3 t/year for industrial waste waters.

Note: Due to the fact that in some BS countries organic phosphorus is not controlled in waste water, it is proposed to use phosphates ($P\text{-}PO_4$) - > 5 t/year for municipal and > 1.5 t/year for industrial waste waters.

– Discharge pollution in terms of oil products (TPHs) - > 0.2 t/year;

– Urban surface run-off (city/town/settlement) with population more than 300.000 in the event when sewage treatment plants are absent. In this case, urban surface run-off is considered a Candidate Hot Spot regardless of the number of tail drains.

In result of this first screening, the sources with negligible contribution to the Black Sea pollution are being excluded from the Total List of LBSs examination and are not considered in the following steps of the HS Methodology application.

At the third stage of the Black Sea Hot Spots Methodology, the following environmental and social ranking criteria are used to screen the List of HSs Candidates and confirm they are Hot Spots in terms of impact as well:

– Waste water discharge volume;

– Distance to the Black Sea (the shortest distance from the area of discharge to the sea);

– Population in town/village, where the point source of pollution is located;

– Type of waste water treatment used;

– Characteristics of flow and mixing in the receiving aquatic environment;

– Level of environmental hazard (taking into consideration the status of the receiving water body);

– Environmental tension at the location of the Hot Spot candidate.

Assigning scores is done by multiplying the weight factor (see above) and the score assigned on the basis of the certain characteristics.

The example for scoring on Column 3 – Waste water discharge volume is giving in Table 1. Wastewater discharge volume is the daily volume of wastewater discharge, th. m^3/day, and allows by the volume of wastewater discharged to assess their potential impact on water quality of the receiving water body.

Depending on the characteristics of hot spots within Stage 3 criterion certain score is assigned (Table 2).

At the fourth stage of the Black Sea Hot Spots Methodology, for a more detailed characterization of the Hot Spots and their prioritization, the following integrated environmental and socio-economic criteria are used:

– Degree of overall impact on water quality
– Degree of local impact on water quality
– Recreation and protected areas
– Level of potential impact on aquatic life, including biota contamination
– Investment attractiveness of the region/ province, and Prospects of development of the region/province

Within each Stage 4 criterion, certain score is assigned (Table 3).

Depending on the amount of final weight of the pollution source, 3 categories (Column 10) of HSs are distinguished:

The Hot Spot of the first rank is an entity that requires most urgent attention and prompt actions from decision makers.

The Hot Spot of the second rank is an entity that requires attention from the decision makers and problem-solving in the short term (3 to 5 years).

The Hot Spot of the third rank is an entity that requires constant attention on the part of decision makers and problem-solving in the medium term (5 to 10 years).

The candidate Hot Spots, outside of the List of top HSs, obviously may later be addressed in the long-term run (over 10 years, however, they should also be included in programmes of measures).

Ranking results.

The Black Sea HSs Methodology was developing during 2 years and that at each step pilot testing was performed [13] for better adjusting of the BS HSs Methodology and Software (data for 2013-2014 were taken). Such approach allowed to find optimal balance between environmental and socio-economic criteria as well as to polish the BS HSs Methodology. The final results of testing are presented below as well as in Table 4:

– *Category 1:* Pivdenni WWTP, Odesa; Sevastopol WWTP; Mykolaev WWTP;
– *Category 2:* Odesa urban surface run-off; Sea commercial port of Illichivsk; Balaklava WWTP; Kherson WWTP;
– *Category 3:* Kerch WWTP; Yevpatoria WWTP; Yalta WWTP.

In Table 4 results of all four testing are also presented.

Final ranking results visualization is presented in Figure 2. As we can see, most HSs are having WW discharges directly to the Black Sea, but there are two HSs (Mykolaev WWTP and Kherson WWTP) which have WW discharges to rivers. Decision-makers should pay attention to all 10 HSs and to implement corresponding measures/projects aimed at improvement of WW treatment efficiency.

CONCLUSIONS.

1. The Black Sea Hot Spots Methodology was developed for identification, assessment and prioritization of Hot Spots, located within the Black Sea catchment area. The BS HSs Methodology includes an expertise scoring (expert-judgment) and mathematical methods for estimating the effect of Hot Spots on the environment of the Black Sea. The list of criteria contains environmental, socioeconomic, and integrative indices.

2. To support the use of the BS HSs Methodology a special database on LBSs was developed; It contains meta data and data on discharges (concentrations and/or loads) of key LBSs. The methodology is equipped with a Software, which allows to automatically connect to the LBS Database and with an additional input of required data/information (which is not part of the LBS Database) to pass through all levels of screening of LBSs and identify which of them are Hot Spots as well as to prioritize them for investment planning.

3. For adjusting the BS HSs Methodology four pilot testing were performed. The final UA HSs lists is as follows: Pivdenni WWTP, Odesa, Sevastopol WWTP and Mykolaev WWTP (Category 1); Odesa urban surface run-off, Sea commercial port of Illichivsk, Balaklava WWTP and Kherson WWTP (Category 2); Kerch WWTP, Yevpatoria WWTP and Yalta WWTP (Category 3).

4. The BS HSs Methodology was proposed to the Black Sea Commission for adoption and regular use in the region which would ensure the BS coastal states evaluate their LBSs in a harmonised way and would help them improve the national investment planning in BS protection. The final list of prioritized UA Hot Spots was presented to the Ministry of Ecology and Natural resources of Ukraine and regional environmental authorities.

This paper was prepared as a follow-up of the project “Integrated hotspots management and saving the living Black Sea ecosystem” (the HBS Project - Black Sea Cross-border Cooperation Programme, financed by European Union, grant agreement 2.2.1.72761.225 MIS-ETC 2303) and the authors gratefully acknowledge the contribution of all colleagues and stakeholders who helped to collect large meta data and data sets, prepare the BS HSs Methodology and its software as well as to develop and nourish the LBSs Database. Special thanks to Violeta Velikova (project partner – SuRDEP, Bulgaria) who has made a great contribution to the BS HSs Methodology. Also without the constant support of Joint Managing Authority of the CBC Programme (JMA, Bucharest, Romania) and Central Finance and Contracts Unit (CFCU, Ankara, Turkey) the work under

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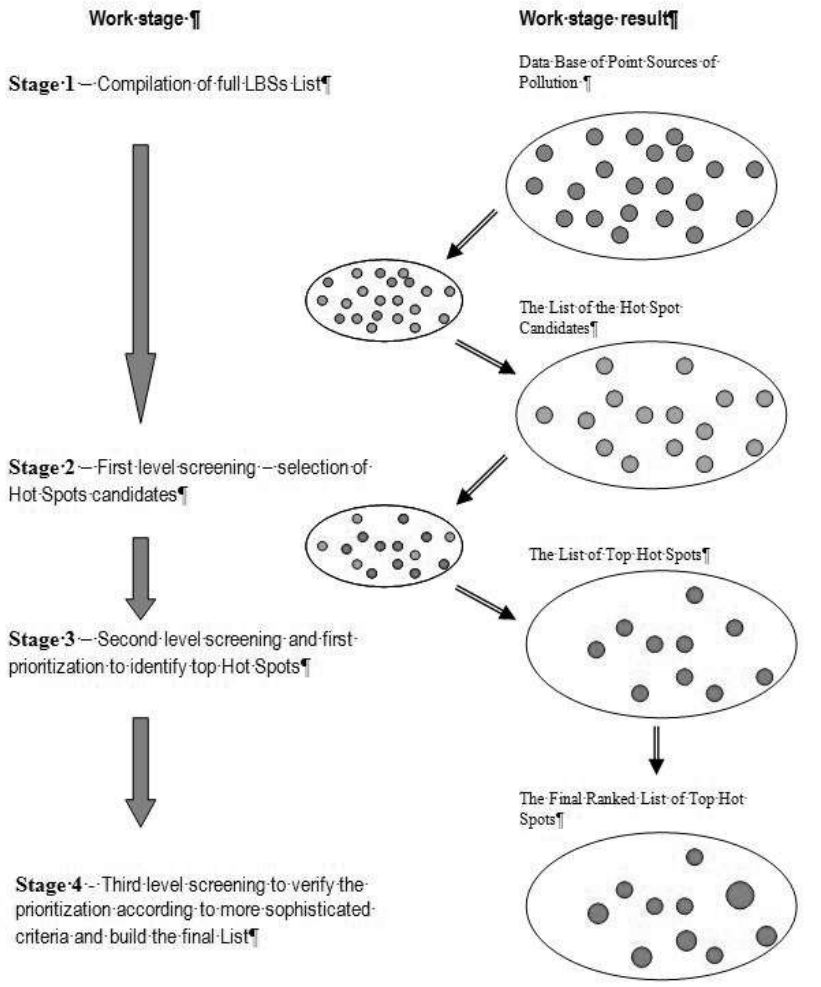

Figure 1 – General Algorithm of the HSs Methodology [10]

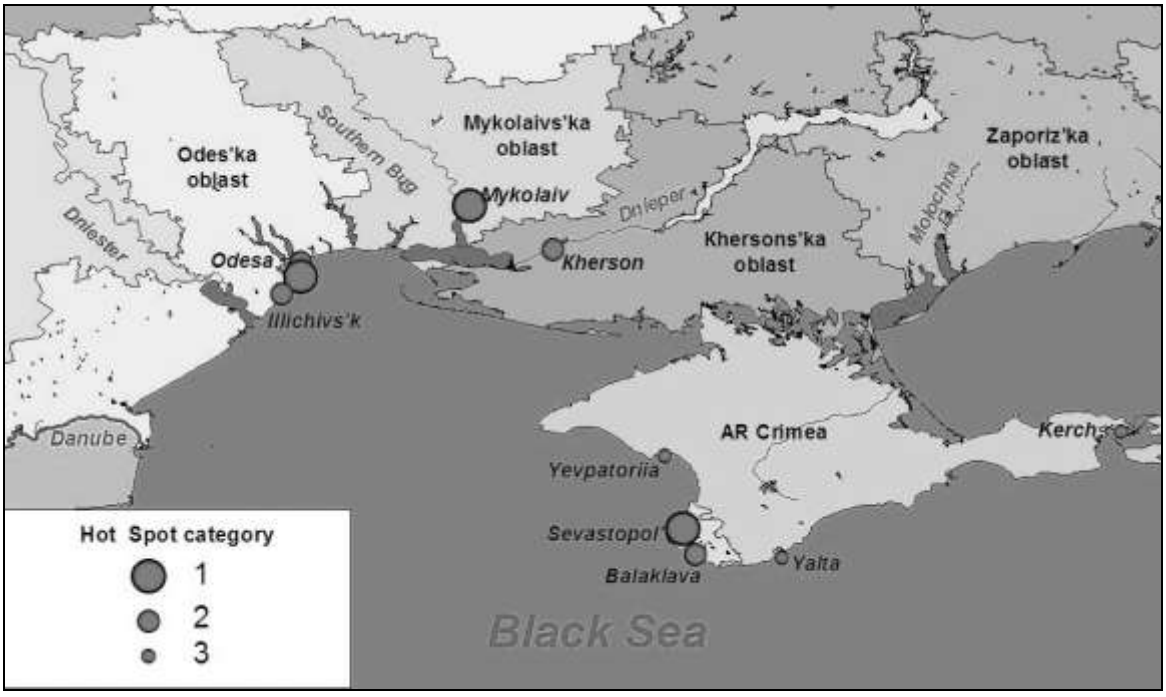

Figure 2 – Final ranked Hot Spots – Ukraine

Table 1 – Scoring for the Column 3 - Waste water discharge volume

Score	**For point sources**	**For urban surface run-off**	
		If data on WW volumes are available	**In the absence of data on WW volumes**
score 1	Discharge volume is up to 10 th. m^3/day	< 5 mln m^3/year	Population of the town is less than 500,000
score 2	Discharge volume is 10 to 50 th. m^3/day	5-10 mln m^3/year	Population of the town is 500,000-1,000,000
score 3	Discharge volume is 50 to 100 th. m^3/ day	10-15 mln m^3/year	Population of the town is 1.0 – 1.5 mln
score 4	Discharge volume is more than 100 th. m^3/day	More than 15 mln m^3/year	Population of the town is more than 1.5 mln

Table 2 – Preliminary Hot Spot description

Name of Hot Spot candidate	Location (town, region, country)	Waste water discharge volume	Distance to the Black Sea or the shortest distance on the aquatic area	Population in town/village, where the point source of pollution is located	Type of waste water treatment used	Characteristics of flow and mixing in the receiving aquatic environment	Level of environmental hazard	Environmental tension on site of the Hot Spot candidate	Final preliminary rank of the Hot Spot candidate
Weight factor		1	0.8	0.8	1	0.8	1	0.8	
…									

Table 3 – Summary List of Hot Spots

Name	Type	Degree of overall	Degree of local impact	Recreation and protected areas	Level of potential impact on aquatic life	Investment attractiveness of the region/province	Prospects of development of the region/province	Weighted total	Category
Weight factor		1.0	0.8	0.8	0.8	from 0.5 to 1	from 0.5 to 1		
…									

Table 4 - Progress in testing results

Existing Hot Spot list [8]	HSs Methodology – Draft 1	HSs Methodology – Draft 2	HSs Methodology – Draft 3	Final HSs Methodology
Industrial Sources	***Category 1***	***Category 1***	***Category 1***	***Category 1***
Brom plant, Krasnoperekopsk	Pivdenni WWTP, Odessa	Odessa urban surface run-off	Pivdenni WWTP, Odessa	Pivdenni WWTP, Odesa
Kamish Burunski iron ore, Kamish Burunsk	Pivnichni WWTP, Odessa	Pivnichni WWTP, Odessa	Sevastopol WWTP	Sevastopol WWTP
Municipal Sources	Sevastopol WWTP	Sevastopol WWTP	***Category 2***	Mykolaev WWTP
Pivdenni WWTP, Odessa	Mykolaev WWTP	***Category 2***	Mykolaev WWTP	***Category 2***
Pivnichni WWTP, Odesa	***Category 2***	Mykolaiv WWTP	Odesa urban surface run-off	Odesa urban surface run-off
Balaklava WWTP	Kerch WWTP	Kherson WWTP	Sea commercial port of Illichivsk	Sea commercial port of Illichivsk
Yevpatoriya WWTP	Kherson WWTP	Balaklava WWTP	Balaklava WWTP	Balaklava WWTP
Sevastpol WWTP	Balaklava WWTP	Sea commercial port of Illichivsk	Kherson WWTP	Kherson WWTP
Yalta WWTP	Yalta WWTP	***Category 3***	***Category 3***	***Category 3***
Gurzuf WWTP	Yevpatoria WWTP	Kerch WWTP	Kerch WWTP	Kerch WWTP
Illichevsk WWTP	***Category 3***	Yalta WWTP	Yevpatoria WWTP	Yevpatoria WWTP
	Feodosia WWTP	Yevpatoria WWTP	Yalta WWTP	Yalta WWTP

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МЕТОДИКА РАНЖИРОВАНИЯ «ГОРЯЧИХ ТОЧЕК» ЧЕРНОГО МОРЯ: ОБЩИЙ ОБЗОР И РЕЗУЛЬТАТЫ ДЛЯ УКРАИНЫ

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Цель. В статье описывается разработанная авторами методика идентификации и ранжирования «горячих точек» Черного моря и приведены результаты ее пилотного тестирования для источников загрязнения, расположенных на территории Украины. Методика разрабатывалась с целью выявления источников загрязнения Черного моря, которые потенциально оказывают наибольшее влияние на экосистему Черного моря, биоразнообразие, здоровье человека, экономическую стабильность. ***Методология.*** В разработанной методике используется поэтапное оценивание значимости различных источников загрязнения. На начальных этапах для выбора из всей совокупности источников загрязнения кандидатов в «горячие точки» применяются простые критерии, не требующие большого количества исходных данных и математических расчетов. На заключительных этапах для ранжирования и категоризации источников загрязнения наряду с критериями, основанными на экспертных оценках, применяются также критерии, основанные на математических расчетах с использованием данных о расходе и составе возвратных вод. В рамках методики разработано компьютерное

приложение, обеспечивающее информационную связь с базой данных источников загрязнения Черного моря, ввод дополнительной информации и выполнение всех необходимых расчетов. ***Результаты.*** Приведены результаты 4-х пилотных тестирований методики для идентификации и ранжирования «горячих точек» Украины, проведенных в 2014-2015 гг. В последней версии методики рассматривались не только промышленные и коммунально-бытовые сбросы возвратных вод в Черное море, но также и поверхностный сток с урбанизированных территорий. ***Научная новизна.*** Основные отличия разработанной методики от методик, применявшихся ранее: 1) использование критериев, основанных на математических расчетах, 2) использование социально-экономических критериев, 3) учет источников загрязнения, расположенных на расстоянии до 200 км от моря. ***Практическое значение.*** Идентификация и ранжирование «горячих точек» Черного моря с помощью разработанной методики может быть использовано для планирования природоохранных инвестиций в черноморском регионе. Разработанная методика предложена Черноморской комиссии для адаптации и использования в регионе.

Ключевые слова: методология, «горячие точки», идентификация, приоритезация, Черное море.