RESULTS OF RANKING LAND-BASED HOTSPOTS, LOCATED WITHIN UKRAINIAN COASTAL ZONE

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Abstract. A methodology for ranking pollution sources is described. It is scientifically well-grounded and can be used for any type of point pollution sources. It includes the level of anthropogenic loading from the hotspot, general anthropogenic loading on the territory and some landscape characteristics. Ten Ukrainian hotspots in the coastal zone were ranked using data for the year 2010. The results were compared with those obtained in 2007. Pivnichi and Pivdenni WWTPs are still on the top of the list. Sudak WWTP has shown the best results (descending 7 ranks). Mariupol, Kerch and Yevpatoria WWTPs have shown the worst results (rising 3 ranks). Ranking of ten Ukrainian hotspots (atmospheric air) was performed using data for the year 2010. Comparison of results with those obtained in 2007 has demonstrated that there are no major changes in the ranks. Two big metallurgical plants are still on the top - Mariupol metallurgical plant Azovstal and Illich Mariupol metallurgical plant. The situation with Crimea soda plant has become much worse (rising 3 ranks).

Key words: methodology for ranking hotspots; point pollution sources; coastal marine waters; air pollution sources; Black and Azov Seas.

1. INTRODUCTION

The Ukrainian coast belongs to two seas: the Black Sea and the Azov Sea, which are very closely linked and should be studied together. Ukrainian coastal zone has unique nature and landscapes; and that is why this area is highly vulnerable to human impact. It has rich natural potential, but there are many industrial enterprises, municipal wastewater treatment plants (WWTPs) and other pollution sources with a significant impact on its environmental state. Therefore, environmental protection and elimination of anthropogenic impact on all components of the coastal zone (coastal waters, atmospheric air and soil, etc.) is a priority at national and international levels. [BSC, 1996; National Program, 2001]

During the development of environmental programs at various levels (regional, national and transboundary), updating of The Strategic Action Plan for the Environmental Protection and Rehabilitation of the Black Sea (Strategic Action Plan) and development of international projects it is necessary to clearly identify and justify what objects have the greatest impact and threat for the environment of the coastal zone (they are also called "hotspots"), in order to consider them for the development and implementation of the relevant environmental measures and activities. Also, in the framework of international obligations Ukraine should send, every year, to the Black Sea Commission a list of 10 hotspots.

The first List of Hotspots in Black Sea coastal states was published in the Transboundary Diagnostic Analyses Report (1996) [BSC, 1996], produced by the UNDP/GEF Black Sea Environment Project. The identification of hotspots was based on Rapid Assessment Methodology [WHO, 1993] and contained the following 10 Ukrainian land-based sources of pollution:

1. Pivdenni WWTP, Odessa oblast;
2. Pivnichni WWTP, Odessa Oblast;
3. Balaklava WWTP, Crimea;
4. Yevpatoria WWTP, Crimea;
5. Sevastopol WWTP, Crimea;
6. Yalta WWTP, Crimea;
7. Gurzuf WWTP, Crimea;
8. Kamish Burunski iron ore WWTP, Crimea;
9. Illichevsk port WWTP, Odessa Oblast;
10. Krasnoperekopsk Brom WWTP, Crimea.

Every year, Ukraine provides a list of hotspots to the Black Sea Commission; however, it has not been changed due to the lack of officially approved methodology of ranking of hotspots.

The National Program for the Protection and Rehabilitation of the Azov and Black Seas Environment [National Program, 2001] was developed and approved for the implementation of the Strategic Action Plan (1996), the Convention on the Protection of the Black Sea Against Pollution (1992) and Ministerial Declaration on the Protection of the Black Sea (1993) at national level. The National Program was developed for the 2001 to 2010 interval and includes a long list of hotspots, located within Black-Azov Seas coastal zone. The hotspots were identified, mainly, based on expert assessment and consultations with local environmental authorities. Currently, a new National Program is under development; for the selection of hotspots, it is necessary to have a scientifically-justified methodology on ranking of hotspots. Moreover, the hotspots should include both water pollution sources and sources of pollution of other components of the environment (air, soil, etc.).

The aim of the article is to present the developed methodology for ranking hotspots (water and air pollution sources) and to compare results of ranking for 2007 and 2010.

2. METHODOLOGY

The developed methodology [Utkina, 2009] can be used for any type of point pollution sources; it includes the level of anthropogenic loading from the hotspot, general anthropogenic loading on the territory and some landscape characteristics (the general scheme is illustrated on Figure 1).

The key feature of the methodology for the land-based point sources of water pollution is that ranking can be performed for hotspots discharging directly to the marine waters, as well as into the rivers, flowing into the sea. The methodology was developed taking into account data availability and format, used in Ukraine, as well as features of the coastal zone.

The methodology includes four steps.

Step 1 – To identify hotspots. For this purpose, official data and information sources, as well as results of previous studies can be used.

Step 2 – To select factors for ranking. It is necessary to mention that factors should be the same for each type of hotspots; however, they will be different for different types of pollution sources. These factors should be significant, and should not overlap.

Step 3 – To fill in the data matrix, that is, to characterize each hotspot using the data associated with factors, selected at step 2.

Step 4 – To perform standardization of the data matrix and to calculate taxonomic distance, by using the multivariate analysis methods. To this purpose, it was decided to use the mathematical method proposed by [Pluta, 1985], allowing to calculate the distance between points in a multidimensional space; linear ordering of points on the basis of taxonomic distance from the reference point allows to calculate the rank of the point, depending upon its impact on the coastal zone environment. This ranking technique is used for different purposes and has produced reliable results.

Key formulas used for standardization of the data matrix are as follows:

$$z_{ij} = \frac{x_{ij} - \overline{x_j}}{S_j} \quad (1)$$

where

$$\overline{x_j} = \frac{1}{n}\sum_{i=1}^{n} x_{ij} \quad (2)$$

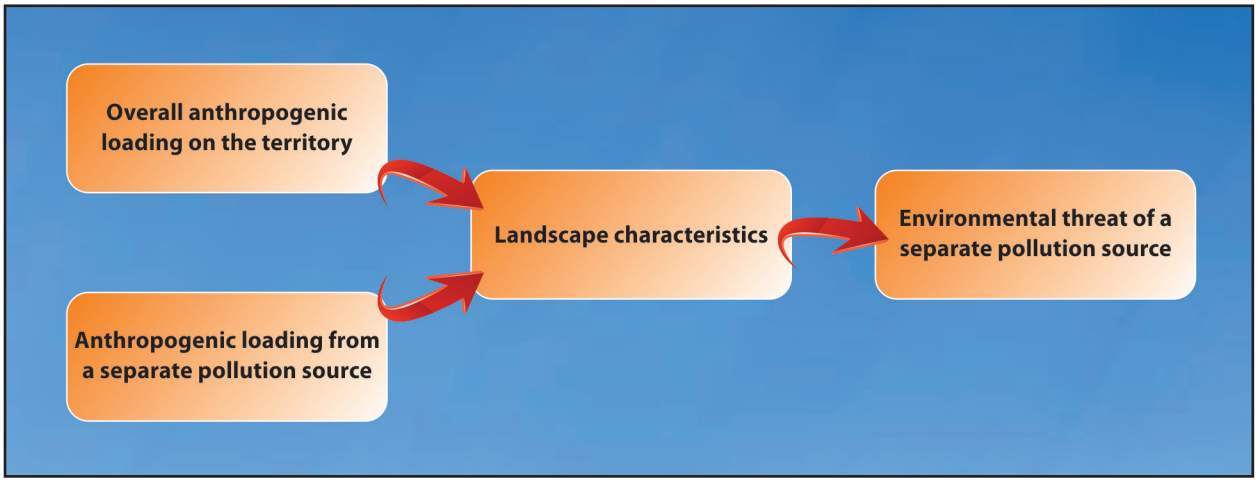

Fig. 1 Scheme for calculation of environmental threat of a separate pollution source

$$S_j = \left[\frac{1}{n} \sum_{i=1}^{n} \left(x_{ij} - \bar{x_j} \right)^2 \right]^{\frac{1}{2}} \quad (3)$$

Conventional signs:

z_{ij} – standardized value of factor j (1,2,…,m) for the object (pollution source) i (1,2,…, n);

$\bar{x_j}$ - arithmetic mean value of factor j for a set of objects;

S_j – standard deviation of factor j;

x_{ij} – non-standardized value of factor j for object i.

Key formulas for calculating the pollution sources rank are as follows:

$$R_i^* = \frac{d_{i0}}{C_o} \quad (4)$$

where dio – taxonomic distance between data-points (x_{ij}) and the upper polar point (x_{0j}), calculated using the formula:

$$d_{io} = \sqrt{\sum_{j=1}^{m} \left(x_{ij} - x_{0j} \right)^2}, \quad \text{where} \quad i = 1,2,...,n. \quad (5)$$

$$C_0 = \left(\bar{x} + \alpha \times sd \right)^2 \quad (6)$$

where

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} d_{i0} \quad (7)$$

$$sd = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(d_{i0} - \bar{x} \right)^2} \quad (8)$$

$$\alpha = 3.$$

The general concept of the methodology is presented on Figure 2.

The developed methodology has the following advantages and characteristics:

- is developed for specific purposes;
- is scientifically well-grounded;
- reflects the features of the region;
- is applicable for ranking of water, atmosphere and soil pollution sources;
- takes into account overall anthropogenic loading;
- includes all significant factors;
- does not require too much data;
- is easy to use.

The developed methodology was applied for ranking point pollution sources in the coastal water zone and air, based on the data of the years 2007 [Utkina, 2009] and 2010. The results are presented below.

3. RESULTS

Ranking of hotspots – coastal water

In 2007, the database on water pollution sources was compiled, using the following official documents:

- Identification and assessment of hotspots in Dnieper Basin, territory of Ukraine: list of 100 big point pollution sources and list of 10 hotspots.
- State of the Black Sea. National report of Ukraine. 1996-2000.
- Report "Inventory of point pollution sources – coastal zone of Azov Sea; their ranking on loading level". 2003

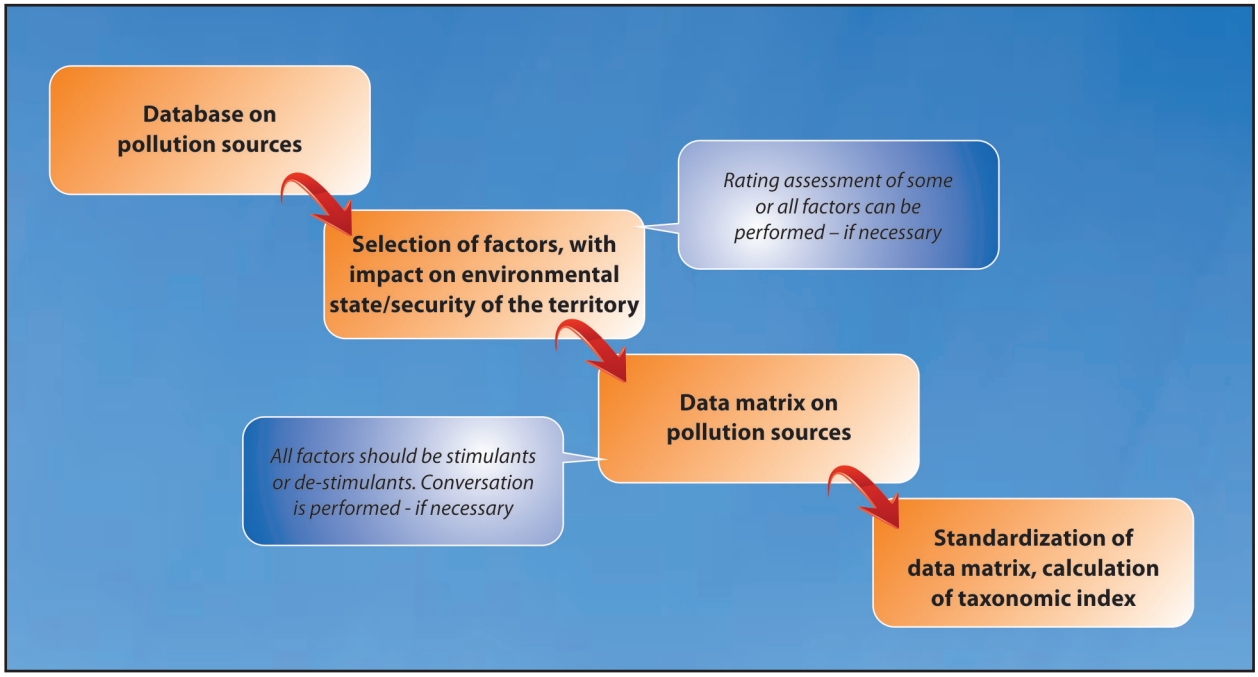

Fig. 2 Methodology on point pollution sources ranking – general concept

- National programme on development of Ukrainian Danube area – approved by the Cabinet of Ministers in 2004.
- Draft of National programme on rehabilitation of the Dniester river basin for the period 2005-2015. 2003.
- Draft of National programme on rehabilitation of the Southern Bug river basin for the period 2005-2015. 2004.

The database includes 53 point pollution sources, both municipal and industrial WWTPs. It was decided to consider hotspots discharging directly into the sea, as well as those located within the river basins.

For water pollution sources, the following factors were selected:

1. Waste water characteristics:
- Waste water discharge (000 m^3/day);
- Concentration of phosphates in waste water (mg/l);
- Concentration of oil products in waste water (mg/l);
- BOD total (mg/l);
- The number of times waste water should be diluted by pure water to correspond to standard requirements.

2. Characteristics of water body, obtained waste waters:
- Water pollution index (conventional unit);
- Average water velocity in the place of discharge (m/sec);
- Distance between pollution source and control point (km).

3. Ecological state of coastal zone section:
- Taxonomic index of territory (conventional unit).

For filling in the data matrix official statistical data were used. The taxonomic index of territory was taken from [Utkina, 2009].

The results confirmed the assumption "hotspots located within river basins can have greater impact than those with discharges directly into the marine waters". [Utkina, 2009]

Thanks to the increasing environmental performance of WWTPs and due to changes in economical activity, the situation may change. That is why it was decided to perform a new ranking, using data for the year 2010 and to compare the ranking results. This time it was decided to concentrate only on the top ten hotspots identified in 2007, all municipal WWTPs located within Black-Azov coastal zone and discharging directly into the sea (Table 1).

As all hotspots have their discharges into the marine waters, the factor "Distance between pollution source and control point" was taken as "0.25 km". New ranking was performed and key conclusions are as follows:
- Category 1 - Pivdenni, Pivnichni and Mariupol WWTPs have the greatest impact on the marine waters;
- Category 2 – Berdyansk and Kerch have great impact on the marine waters;
- Category 3 – Sevastopol, Yevpatoria and Feodosia WWTP have big impact on the marine waters;
- Category 4 – Dzhankoi and Sudak WWTPs have significant impact.

The results were compared with the ones obtained for the year 2007 (see Table 1).

Comparison of results:
- Sudak WWTP showed the best results (descending 7 ranks);
- Situation on Dzhankoi WWTP improved (descending 2 ranks);
- Environmental threat of Sevastopol WWTP has become lower (from rank 5 to rank 6);
- Situation on Pivdenni, Pivnichni and Berdyansk WWTPs remained unchanged;
- Mariupol, Kerch and Yevpatoria WWTPs had the worst results (rising 3 ranks);
- Situation on Feodosia WWTP became a little bit worse (rising 1 rank).

Changes in ranks can be explained by the environmental performance improvement and/or changes in economic activity.

Ranking of hotspots – atmospheric air

In 2007, the database on atmospheric air pollution sources was compiled, based on the Ecological Atlases of Oblast (administrative units of Ukraine). The database includes 18 hotspots located within the Black-Azov Seas coastal zone. They are all big industrial enterprises with significant environmental impact.

For air pollution sources, the following factors were selected because of being most significant:

A. Key emissions:
- CO;
- NO_x;
- SO_2;
- CH_4;
- NH_3;
- Solid particles;
- Non-methane volatile organic substances.

B. Taxonomic index of territory.

For filling in the data matrix, official statistical data were used. The taxonomic index of territory was taken from [Utkina, 2009].

The results allowed to identify hotspots where emergent actions were necessary. As with municipal WWTP hotspots it was decided to carry out a new ranking using data for the year 2010 were taken and considering the 10-top hotspots identified in 2007 (see Table 2).

New ranking results are as follows:
- Category 1 - Mariupol metallurgical plant Azovstal and Illich Mariupol metallurgical plant, Donetsk Oblast have the greatest impact on the environment;
- Category 2 - Odessa port plant and Odessagas, Odessa City have a great impact;

Table 1 Results of ranking of hotspots – in the coastal water zone, in 2007 and 2010.

Rank	Year	
	2007 [Utkina, 2009]	2010
1	Pivdenni WWTP	Pivdenni WWTP
2	Pivnichni WWTP	Pivnichni WWTP
3	Sudak WWTP	Mariupol WWTP
4	Berdyansk WWTP	Berdyansk WWTP
5	Sevastopol WWTP	Kerch WWTP
6	Mariupol WWTP	Sevastopol WWTP
7	Dzhankoi WWTP	Yevpatoria WWTP
8	Kerch WWTP	Feodosia WWTP
9	Feodosia WWTP	Dzhankoi WWTP
10	Yevpatoria WWTP	Sudak WWTP

- Category 3 - Illichevsk oil extraction plant, Odessa Oblast, Infoxvodokanal, Odessa City, Titan plant and Crimea soda plant, Crimea, and Yugzement plant, Mykolaiv Oblast have a big impact on the atmospheric air;
- Category 4 - Kherson oil processing plant, Kherson City has significant impact.

The obtained results were compared with those, received in 2007 (see Table 2).

Comparison of results:

- There are no big changes in the ranks. Two big metallurgical plants are still on the top - Mariupol metallurgical plant Azovstal and Illich Mariupol metallurgical plant.
- In most cases the situation has become a little bit better (Odessa port plant, Mariupol metallurgical plant Azovstal, Kherson oil processing plant – lowering on 1 rank) or a little bit worse (Illich Mariupol metallurgical plant, Odessagas, Infoxvodokanal, Yugzement plant – rising on 1 rank);
- The situation with Crimea soda plant has become much worse – rising 3 ranks.

The new ranking can be explained by changes in environmental performance of enterprises, in produced materials or used raw materials, in emissions from other hotspots, introduction of new technologies, etc.

4. CONCLUSIONS

A. The developed methodology is scientifically well-grounded and can be used for any type of point pollution sources. It includes the level of anthropogenic loading from the hotspot, general anthropogenic loading on the territory and some landscape characteristics. It requires mainly availability and free access to official statistical data. The methodology is recommended for updating of the list of hotspots, located within the Ukrainian coastal zone, for development

Table 2 Results of ranking of hotspots – atmospheric air, 2007 and 2010.

Rank	Year	
	2007 [Utkina, 2009]	2010
1	Mariupol metallurgical plant Azovstal	Illich Mariupol metallurgical plant
2	Illich Mariupol metallurgical plant	Mariupol metallurgical plant Azovstal
3	Odessa port plant	Odessagas
4	Odessagas	Odessa port plant
5	Illichevsk oil extraction plant	Crimea soda plant
6	Titan plant	Infoxvodokanal
7	Infoxvodokanal	Illichevsk oil extraction plant
8	Crimea soda plant	Titan plant
9	Kherson oil processing plant	Yugtzement plant
10	Yugtzement plant	Kherson oil processing plant

of national and international environmental protection actions and projects.

B. Ranking of 10 hotspots – WWTPs discharging directly to marine waters - was performed by using data for the year 2010. Comparison of results for the years 2007 and 2010 allows to say that:

- Sudak WWTP showed the best results (descending 7 ranks);
- Situation on Dzankoi WWTP changed to the better (descending 2 ranks);
- Environmental threat of Sevastopol WWTP has become lower (from rank 5 to rank 6), while situation on Feodosia WWTP worsened (rising on 1 rank);
- Hotspots Pivdenni, Pivnichni and Berdyansk WWTPs remained unchanged;
- Mariupol, Kerch and Yevpatoria WWTPs have shown the worst results (rising 3 ranks).

Changes in ranks can be explained by the environmental performance improvement and/or changes in economical activity.

C. Ranking of 10 hotspots – atmospheric air pollution sources - was performed by using data for the year 2010. Comparison of ranking results for the years 2007 and 2010 allows to say that:

- There are no big changes in the ranks. Two big metallurgical plants are still on the top - Mariupol metallurgical plant Azovstal and Illich Mariupol metallurgical plant.
- In most cases, the situation become either a little bit better (Odessa port plant, Mariupol metallurgical plant Azovstal, Kherson oil processing plant – lowering on 1 rank) or a little bit worse (Illich Mariupol metallurgical plant, Odessagas, Infoxvodokanal, Yugtzement plant – rising on 1 rank);
- The situation with Crimea soda plant worsened - rising 3 ranks.

The new rankings can be explained by changes in environmental performance of enterprises, in produced materials or used raw materials, in emissions from other hotspot , introduction of new technologies, etc.

REFERENCES

BSC (1996). Transboundary Diagnostic Analyses Report (1996) - http://www.blacksea-commission.org/.

National Program (2001). National Program for the Protection and Rehabilitation of the Azov and Black Seas Environment approved by the Law of Ukraine Nr 2333-III dated 22.03.2001.

Pluta W. (1985) Wyznaczanie segmentow w metodzue dekompozycji autnomicznej / Pluta W. // Prace Naukowe AE we Wroclawiu. – 1985 – *In Polish*.

Utkina K. B. (2009). Geoenvironmental Assessment of Coastal Zone in the Ukrainian Part of the Azov/Black Sea Basin – PhD thesis – 2009 – *in Ukrainian*.

WHO (1993). Guide to Rapid Source Inventory Techniques and their Use in Formulating Environmental Control Strategies. In two parts / World Health Organization. Geneva, 1993.