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Analysis of Sediment Contamination in the Harbour of Skikda

M. Kherouf*, R. Mansouri and M. Guenfoud

Laboratoire de Génie Civil et d'Hydraulique; B. P 401 Université de Guelma, 24000, Algérie

✉ kherouf_maz@yahoo.fr

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Abstract: The aim of this work is the study of the vast pollution in harbours occurred due to the high intense hydrodynamism, which involves the sedimentation of pollutant substances. Some of these substances could have a toxic character, like heavy metals. In this work, chemical analyses were carried out on samples taken from the studied area. The results were treated using an approach, which enables us to distinguish the dredged sediment, according to their contamination level, and their potential toxicity. Using a simplified method, the already mentioned approach allows the determination of the risk levels, taking into account the actual codes, and also makes help to differentiate between dredged sediments, thus bringing a decision-making aid for managers.

Key words: Harbour of Skikda, sedimentation, contamination, risk levels, pollutant substances.

Introduction

The harbour structures are generally established in zones where the depth of water is relatively low. It is then essential to carry out dredging in order to facilitate the navigation in harbours. These dredging are carried out periodically to remove the sediments which accumulate in the channels. In countries bordering the Atlantic Ocean and the North Sea, the annually dredged sediment is about 70 to 85 million tons, which are rejected in the sea or are stored in selected zones (Abdelrhman and Dettmann, 1993). The coastal sediments contain many chemical substances, containing organic and inorganic components (see Table 1), and they could have a toxic character: heavy metals, poly-aromatics, organo-chlorinated hydrocarbons (PCB), various pesticides and biocides.

The risk is a parameter that characterises an undesirable even to its occurrence probability and to its damages accentuations. For a given target, in a given context, an accidental risk can thus be estimated by applying the following relation:

$$\text{Risk} = \text{Damages} \times \text{Probability} \quad (1)$$

*Corresponding Author

Table 1: Concentrations while contaminating in materials dredged from 1986 to 1993

Concentration (mg/kg)	*The Munch/ North sea*	*The Atlantic Ocean*	*The Mediterranean sea*
Mercury	0.15-1.45	0.05-0.19	1.16-2.51
Cadmium	0.5-0.95	0.27-0.64	0.27-0.64
Arsenic	3.9-13.8	4.4-28.7	10.4-11.2
Lead	36-59	41-75	93-357
Chromium plate	38-65	37-75	56-74
Copper	18-35	10-53	107-745
Zinc	105-175	60-180	274-506
Nickel	12-17	6-39	25
PCB	0.01-0.14	0.005-0.1	0.1-0.81

Source: Geode

The levels suggested by Geode (French interdepartmental Group) were used for a first evaluation of the risk, with an aim of defining a strategy and a tool of decision-making aid as regards management of the contaminated sediments.

Choice of Parameters

Analysis of the chemical substances risks in the environment is a recent procedure that uses toxicity intrinsic information and their level of presence in water. Its objective is the evaluation of the perturbation risks. The chosen strategies for the guide elaboration values are based on a statistic exploitation of measured contaminant concentrations (Robbe, 1989). The Gauss-arithmetic distribution examination enables the determination, for the called noise value (identifiable entropic Robbe) (Alzieu, 1999), the contribution of each contaminant. The significance of two levels codes, for metals, is defined by guidelines of the Oslo convention (see Table 2).

Level 1: Values less than immersion which is authorized without a particular study.
Level 2: Values greater than the immersion which is suspected to be not allowed if the constituted solution is not the less prejudicial one for the environment.

Table 2: Reference levels for heavy metals (in mg/kg dry sediment)

Metals	*Level 1 (mg/kg)*	*Level 2 (mg/kg)*
Arsenic	25	50
Cadmium	1.2	2.4
Chromium	90	180
Copper	45	90
Mercury	0.4	0.8
Lead	100	200
Nickel	37	74
Zinc	276	552

In accordance with their definitions mentioned above, the code values are used to define a strategy (decision tree) which is a device (Geodrisk program) that helps making decision in the case of sediment management (see Figure 1). Also, sediments that have at least one value equal or more than level 1 are subjected to a risk study.

Steps Followed for Analysis

The steps followed should take into account, successively, the under mentioned fields:

- The potential hazard of each contaminant
- The measured toxicity of the sediment
- The potentiality of the transfer of the contaminants starting from the delivery point
- Sensitivity of the receiving ecosystem.

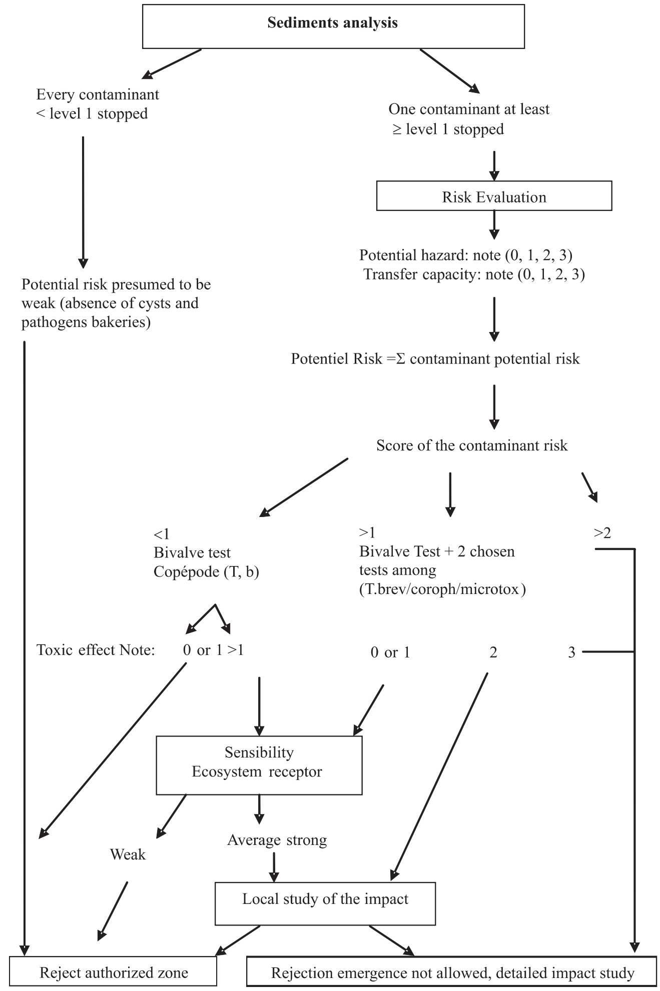

Figure 1: The decision tree.

For each field, some risks criteria are specified and to which notes ranging between zero and three are attributed. The latter values are determined from bibliographical data for biogeochemical and toxicity of the considered contaminants (see Table 3).

Table 3: Criteria and notes of risks for the estimation of the potential hazard of sediments

Criteria of hazard	*Notes of risk*			
Potential	0	1	2	3
Concentration: Dm	<0.5	0.5 to 1	1 to 1.5	>1.5
Affinity dissolved phase: log Kd		>5 Pb	4.5 to 5 Hg, Cu, Zn	<4.5 Cd, PCB
Bioconcentration: log FBC		<2	2 to 3 Cd, Pb, Cr, Zn	>3 Hg, Cu, PCB
Potential toxicity			Cu, Zn, CrVI, Pb	PCB, Hg, Cd, TBT

Potential Hazard

The criteria of potential hazard and their associated notes of risks, indicated in Table 3, take into account:

- The concentration of the contaminant in the sediment compared with its value in level 1; the Dm value (going beyond level 1) is equal to the relation the concentration/level 1.
- The affinity for the dissolved phase; explained by the coefficient of division between the solid phase and water (Kd) for both the inorganic contaminants and in the case of the organic substances by Kow, coefficient of division between the octanol and the water, which expresses their lipophilic character.
- The bio-concentration, determined by the factor of bio-concentration (FBC), for the organic substances, can be calculated starting from Kow.
- The potential toxicity evaluated on the basis of bibliographical data.

Transfer

The term of transfer covers at the same time the transport of the pollutant and accessibility to a given target and related aspects. It is difficult to quantify and can be generally evaluated by considering a decreasing scale of containment: tight containers (note 1), weak erosion of the deposit (note 2) or strong (note 3).

Sensitivity of the Ecosystem

The attribution of the notes of risk takes into account the local conditions such as: no ecosystem of major interest in the influenced zone of the rejection (note 1), targets in intermediate position or risk of occasional exposure (note 2), proximity of zones of biological or tourist production whose immersion can have consequences on healthiness (pathogenic bacteria, toxic phytoplankton), (note 3).

Score of Risk

The calculation of the total risk score of the sediment takes into account, for each analyzed contaminant, in the first stage the potential and the transfer hazard scores and, in the second stage the measured toxicity and ecosystem sensitivity scores, according to relation (2):

$$\text{Risk} = [DI \,.\, Qc].\,[(M + B)\,.\,Cn]\,.\,[V] \qquad (2)$$

where DI is potential toxicity value (from 0 to 3); Qc – concentration value while contaminating (from 0 to 3); M – dissolved phase affinity value (from 1 to 3); B – note bio-concentration (from 1 to 3); Cn – note transfer (from 1 to 3); V – note sensitivity ecosystem (1 to 3).

Total Toxicity of Sediments

The analysis of the potential dangers can be realised on only a limited number of contaminants. It is necessary to integrate, at the same time, the real bio-availability and toxicity of a possible substances not detected by the chemical analysis. This analytical result indicates the total toxicity of the sediment, using one or more laboratory bio-tests. Several tests are proposed for an evaluation toxicity of the sediments. Based on a comparative study, carried out in several French harbours, the following four tests are recommended (Quiniou et al., 1997):

- Embryo toxicity of fertilized eggs of bivalve: the hollow oyster (Crassostrea gigas.C.g) or moulds it (Mytilus edulis.M.e);
- Solid Microtox® phase;
- *Corophium* sp;
- Marine Copepod *Tigriopus brevicornis*.

Application on Skikda Harbour

The Skikda harbour has played a predominant role since long time. The initial small port was constructed in 1861, during the colonial period. This demonstrates the history and age of the Skikda Port. Some of the principal developments, in the period ranging from 1891 to 1964, are the construction of new platforms and new quays. In 1969, it was decided that the port would be transformed into a mixed port including several oil jetties. In 1981, a phase of adjustments was constructed to increase the harbouring capacity of the mixed port. Actually, and in order to respond, as well as possibly, to increase traffic and to deal with the spectacular rise in the number of containers, the Company plans to complete its studies to develop a scheme for the future of the port until the year 2015. The mixed port of Skikda, located between longitude 6°54′30″ and the Northern latitude 36°53′20″, has the characteristics enumerated in Table 4.

Table 4: Harbour's characteristics

Maritime access	120 m length 15 m depth
Basins	Before port: 26 hectares Wet dock: 17.3 hectares
Turning circle	350 m
Length of the principal pier	1625 m
Surface water level	45 hectares
Capacity of the harbour station	3300 passengers
Capacity of the station: passenger car	18 vehicles at the same time

Hydrodynamic Situation

The Skikda district is oriented towards the North-East sector, thus the winds of this sector coming are the most dominant and often are at the origin of the most significant disturbances. In the Skikda basin a tide of a 12 hours period and of a low amplitude of about 0.30 m generally occurs. It can be concluded that the Skikda port is characterised by North West to north and also by North-North East to North East directed tides which rarely exceed the height of 4 metres (see Figure 2) (Hocini and Mami, 1991).

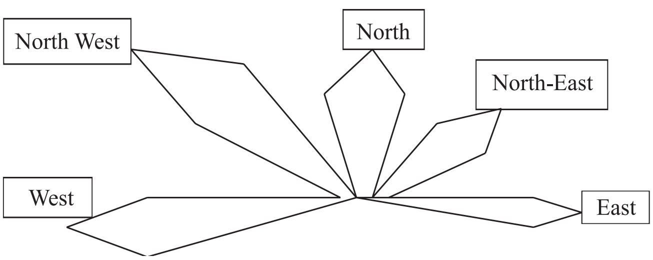

Figure 2: Rose of the swells by sector.

The evaporation, the packing and the increase in density enhance the sedimentation of some hydrocarbons. It was also noted that the floating hydrocarbons move approximately under the action of the wind with a speed of about 3% of that of the wind. In the presence of surface currents, the additional displacement of hydrocarbons is equal to that of the currents and will be added to the induced movement of the wind (see Figure 3). The dimension, the force and the direction of the tide currents must be taken into account if the prediction of the hydrocarbons displacement is needed.

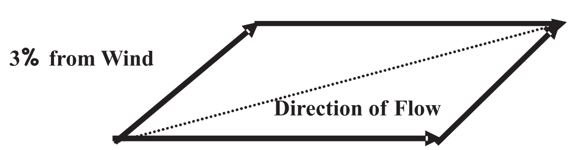

Figure 3: Direction of sediment transport.

Sediment Analysis

The analyses of sediments, 14 samples, were worked on, at a rate of nine principal elements (Zn, Cd, Cu, Mn, Ni, Cr, Pb, Fe, and Hg) for two stations whose characteristics are reported in Table 5.

Table 5: Characteristics of the stations

	Old port	*New port*
Temperature (°C)	26.00	26.05
Depth (m)	7.50	7.00
Outdistance shore (m)	200	150
Nature of the sediment	sand	sand

Sedimentation is unevenly distributed over the basin and may reach over 2 cm/year in certain areas. Sediments reach from very fine silts < 0.01 mm to fine sand ~0.1 mm. There are two reasons for this heavy sedimentation. The first but only minor sediment intrusion originates from the flow induced water exchange and from this resulting vortex generation in the harbour entrance. The second and more sediment producing effect comes from the continuous exchange of sediment leaden waters from the river due to rising tides, the so-called tide effect. Solution for reduction in maintenance dredging therefore can only come from a reduction in flow induced water exchanges between the inlet and the harbour and a concept for guidance of inflows and sedimentation so that access to berthing areas is secured. The sediment samples were realized during the month of November 2003 for the considered area and the concentration of nine cited above is determined. Table 6 gives the concentration results of the sediment in mg/kg.

Table 6: Concentration results of pollutant

Metallic Pollutant	*Zn*	*Cu*	*Mn*	*Ni*	*Cr*	*Pb*	*Cd*	*Fr*	*Hg*
Found Concentration (mg/kg)	85	45	115	35	38.5	145	0	14935.5	1

Elementary Value of the Risk

The elementary value of the risk is the score risk ranging from 0 to 3 which is calculated using an informative basis, on one of the contaminants when levels of reference were fixed. Table 7 gives the result of the elementary value of the risk for each contaminant.

It appears that for mercury (Hg) the elementary score of risk is greater than 2 in the port of Skikda. In other words, the immersion in this port must take into account a deep impact study. But from the hydrodynamic sedimentary view, the modelling of the dredging rejections must treat processes, which, partially, are not specific to dredging problem.

Table 7: Results of the elementary value of the risk

Contaminant	*Cd*	*Cr*	*Cu*	*Hg*	*Ni*	*Pb*	*Zn*
Concentration (mg/kg sec)	1.5	44.25	18	2.01	38	36.50	62.25
Affinity dissolved phase	3	3	2	1	3	1	2
Bio-accumulation	2	2	2	3	1	2	2
Capacity of transfer	2	2	2	2	2	2	2
Potential toxicity	3	2	2	3	1	2	2
Elementary value of the risk	1.2	0.4	0.4	3.0	1.0	0.3	0.2

Total Score Risks

The total score risks aims is to distinguish between the weak, medium or strong risks. In this way it does not propose a clear decision based on mathematical limits, but it helps in decision-making after taking into account the whole identified potential hazard. In our case, the score risk is 1.2 and is calculated for seven elements because cadmium (Cd) has concentration of 0. Concerning measurements when concentrations are lower than level 1, the potential risk is supposed to be weak and chemical analysis results risks can be considered as not very instructive.

If the score risk is lower than 1

It is important to know the toxicity of sediments, in order to take into account the effects of contaminants exceeding level 1 of decree. In this case, only one toxicity test can be sufficient; it is then recommended to carry out, preferably, the embryonic development test of the bivalves or the copepod marine *tigriopus brevicornis* test. If one of the test results indicates a neglected or a weak effect (one), the rejection or the immersion can be considered.

If the score risk lies between 1 and 2

In this case, the toxicity evaluation will be carried out starting from three tests, the first one is the embryonic test, the second is the marine test copepod and the third one is between *Corophium* sp or Microtox® (*Vibrio fischeri*) solid phase. The most unfavourable value of the effect for these three tests considered are taken into account. If the note corresponds to a negligible or a weak effect the sensitivity of the zone of immersion should be considered. And if the note corresponds to a medium effect the local impact study has to be carried out. If the value corresponds to a strong effect the immersion cannot be authorized without an impact study.

If the score risks contaminant is higher than 2

In this case the immersion cannot be authorized without a deep impact study which brings the proof that it constitutes the unacceptable solution for the environment.

Conclusion

In this study, the evaluation of the ecological risks of the dredged sediments harbour using a simple approach is carried out. This approach is a tool that makes possible to differentiate the dredged sediments, according to the level of contamination, the potential and the measured toxicity, thus bringing a decision-making aid for the managers and shows if an impact study is necessary.

The local impact study can be considered as the final combined results based on all the collected values for the studied immersion site. At this stage, the sensitivity of the immersion area has to be considered.

The main object of the impact study is to confirm that the immersion constitutes the least test solution for the environment. Concerning mercury and lead the elementary risk score is greater than 2 in the study area that means that the immersion in the harbour should be followed by an impact study.

Finally, the approach used in our study includes both the guide's values and the results of the selected toxicity test, in order to evaluate the environmental risks due to the sediments immersion, particularly for those in which the contamination is located between levels 1 and 2.

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