Journal of Engineering and Applied Sciences 2 (2): 416-420, 2007

Simulation of the Sediment Transport in Harbours

Kherouf Mazouz, Rachid Mansouri and Mohamed Guenfoud
Laboratoire de Génie Civil et d'Hydraulique, Université de Guelma BP 401, Guelma 24000, Algérie

Abstract: The high hydrodynamism in harbours involves the sedimentation of pollutant substances. Some of these substances could have a toxic character, like heavy metals. In this study, a number of chemical analyses were carried out on samples taken from the studied area. The results were treated using software, which enables us to distinguish the dredged sediment according to their contamination level and there potential toxicity. Using a simplified method, the already mentioned software allows determining the risk levels taking into account the actual codes. The occurred changes of the velocity field, favourite the transport of these substances and their sedimentation in harbours. The simulation of the hydrodynamism and the sediment transport were made using the models RMA2 and SED2D. Hence, solutions to the localisation of the sedimentation areas can be achieved in order to facilitate the dredging operations. A reduction of the sediment intrusion is possible when an appropriate harbour basin conception is considered.

Key words: Harbour, sedimentation, heavy metals, pollutant, hydrodynamism

The risks analytical steps: The risk is a parameter that characterises an undesirable even to its occurrence probability and to its damages accentuations for realisation. Analysis of the chemical substances risks in the environment is a recent procedure that, using toxicity intrinsic information and their level presence in water. Its objective is the evaluation of the perturbation risks. The chosen strategies for the guide elaboration values based on a statistic exploitation of measured contaminant concentrations during plural-years companies (Quiniou *et al*., 1997) The Gauss-arithmetic distribution examination enables the determination for the called noise value, in others words its identifiable entropic (Robbe, 1989), contribution for each contaminant. The signification of two levels codes, for metals is defined by guidelines of the Oslo convention (Alzieu, 1999).

Level 1: values less than which immersion is authorized without a particular study;

Level 2: values greater than which the immersion is suspected to be not allowed if the constituted solution is not the less prejudicial one for the environment shown in Table 1.

In accord with their definition above mentioned, the code values are used to define a strategy (decision tree) is devices (Geodrisk program) which help making decision in the case of sediment management. Also, sediments that have at least one value equals or more than level1 are subjected to a risk study show in Fig.1.

Table 1: Reference levels in (mg kg^{-1} dry sediment) for heavy metals

Metals	Level 1 (mg kg^{-1})	Level 2 (mg kg^{-1})
Arsenic	25	50
Cadmium	1.2	2.4
Chrome	90	180
Cuivre	45	90
Mercure	0.4	0.8
Plomb	100	200
Nickel	37	74
Zinc	276	552

Application at skikda port: The district of Skikda is situating in the north-east of Algeria. It has to be noted that the presence of a low tide of a 12 h period and a weak amplitude for instance 0.30 m. On the other hand, the Skikda region is characterized with the predominance of North-North storms having the amplitudes superior than 1 m and rarely greater than 4 m and Noth-Ouest storms amplitude of which can be greater than 8 m (Hocini and Mami, 1991).

Samples: The sediment samples were realized during the month of November 2003 for the considered area and the concentration of 9 elements (Zn, Cu, Mn, Ni, Cr, Pb, Fe, Hg) is determined. Table 2 gives the concentration results of the sediment in mg kg^{-1}.

Elemental value of the risk: From the Table 2 and 3, it is noted that for mercury the score is greater than 2, this means that the immersion in this harbour must take in account of a detailed impact study. Form the

Corresponding Author: Kherouf Mazouz, Laboratoire de Génie Civil et d'Hydraulique, Université de Guelma BP 401, Guelma 24000, Algérie

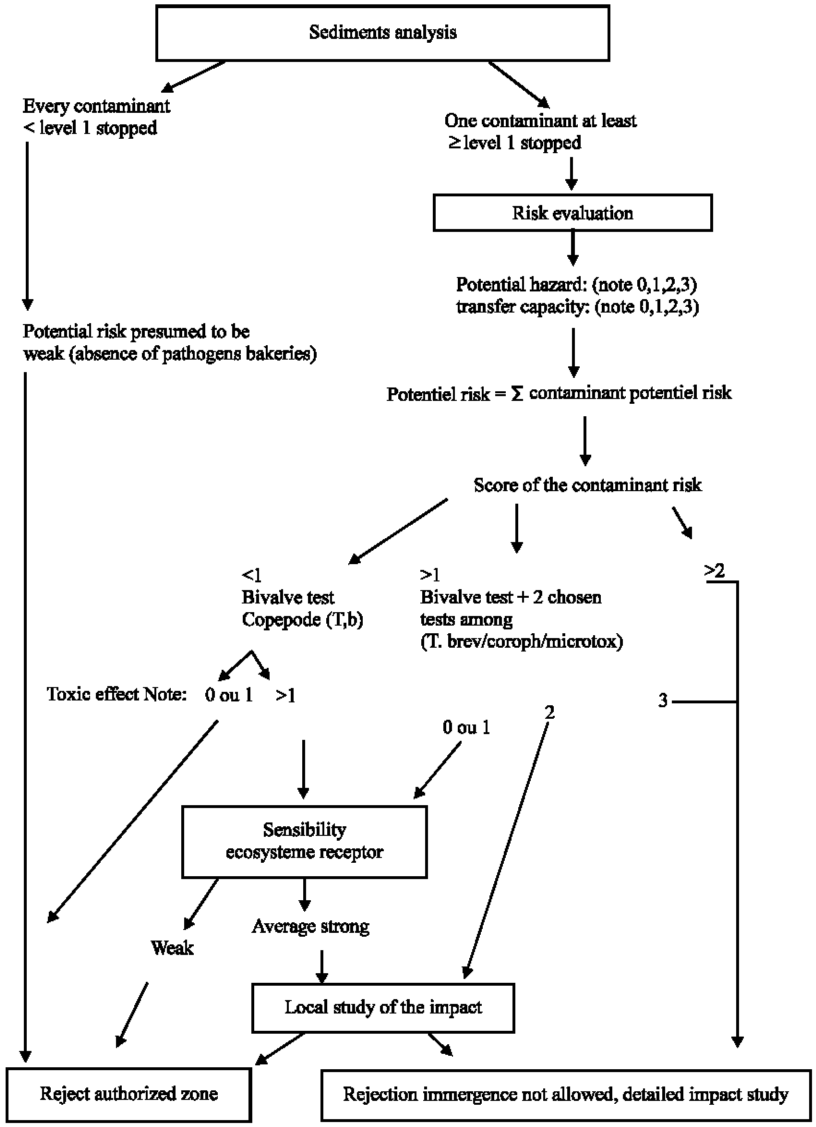

Fig. 1: Decision tree

Table 2: concentration results of polluants analysis

Metallic polluant	Zn	Cu	Mn	Ni	Cr	Pb	Cd	Fr	Hg
Found Concentration (mg kg^{-1} dry)	85	45	115	35	38.5	145	0	14935.5	1

Table 3: Elemental value of the risk results

Contaminant	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Concentration (mg kg^{-1} sec)	1.5	44.45	18	2.01	38	36.50	62.25
Dissolved phase affinity	3	3	2	1	3	1	2
Bioaccumulation	2	2	2	3	1	2	2
Transfert capacity	2	2	2	2	2	2	2
Potentiel toxicity	3	2	2	3	1	2	2
Elemental value of the risk	1.2	0.4	0.4	3.0	1.0	0.3	0.2

sedimentation hydrodynamism point of view, the simulation of a dragged rejection must treat processes that, in parts, are not specified to dragged problems.

MODELISATION

The hydrodynamic model (RMA2): RMA 2 is a two dimensional depth averaged finite element hydrodynamic numerical model. It computes water surface elevations and horizontal velocity components for sub critical, free-surface flow in two dimensional flow fields. The model computes a finite element solution of the Reynolds from the Navier-Stockes equations for turbulent flows.

Friction is calculated with the Manning's or Cheesy equation and eddy viscosity coefficient are used to define turbulence characteristics. Both steady and unsteady state problems can be analysed. The generalized computer program RMA 2 solves the depth-integrated equations of fluid mass and momentum conservation in two horizontal directions (Roig *et al*., Schwarze and Muller, 1995; US Army Corps of Engineers, 1995). The forms of the solved equations are:

$$h\frac{\partial v_x}{\partial t}+h\cdot v_x\frac{\partial v_x}{\partial x}+h\cdot v_y\frac{\partial v_y}{\partial y}-\frac{h}{\rho}\left(E_{xx}\frac{\partial^2 v_x}{\partial x^2}+E_{xy}\frac{\partial^2 v_x}{\partial y^2}\right)+g\cdot h\left(\frac{\partial \alpha}{\partial x}+\frac{\partial h}{\partial x}\right)+\frac{g\cdot v_x\cdot n^2}{h^{1/3}}+\left(v_x^2+v_y^2\right)^{1/2}-\xi\cdot v_a^2\cos\psi-2\cdot h\cdot\omega\cdot v\cdot\sin\phi=0 \quad (1)$$

$$h\frac{\partial v_y}{\partial t}+h\cdot v_x\frac{\partial v_y}{\partial x}+h\cdot v_y\frac{\partial v_y}{\partial y}-\frac{h}{\rho}\left(E_{yx}\frac{\partial^2 v_y}{\partial x^2}+E_{yy}\frac{\partial^2 v_y}{\partial y^2}\right)+g\cdot h\left(\frac{\partial \alpha}{\partial y}+\frac{\partial h}{\partial y}\right)+\frac{g\cdot v_y\cdot n^2}{h^{1/3}}+\left(v_x^2+v_y^2\right)^{1/2}-\xi\cdot v_a^2\sin\psi+2\cdot h\cdot\omega\cdot v\cdot\sin\phi=0 \quad (2)$$

$$\frac{\partial h}{\partial t}+h\left(\frac{\partial v_x}{\partial x}+\frac{\partial v_y}{\partial y}\right)+v_x\frac{\partial h}{\partial x}+v_y\frac{\partial h}{\partial y}=0 \quad (3)$$

Where:

h	:	Depth (m)
u,v	:	Velocities in the Cartesian directions (m/s)
x,y	:	Cartesian coordinates (-)
t	:	Time(s)
ñ	:	Density of fluid (kg m^{-3})
E	:	Eddy viscosity coefficient (-)
g	:	Acceleration due to gravity (m/s^2)
a	:	Elevation of bottom (m)
n	:	Manning's roughness (s $m^{-1/3}$
1.486	:	Conversion from SI (metric) to non-SI units
æ	:	Empirical wind shear coefficient (-)
V_a	:	Wind speed (m/s)
Ø	:	Wind direction (°)
ù	:	Rate of earth's angular rotation (°)
ϕ	:	Local Latitude (°)

The transport sediment model (SED2D): SED-WES can be applied to clay or sand bed sediments where flow velocities can be considered two dimensional in the horizontal plane (i.e., the speed and direction can be satisfactory represented as a -depth-averaged velocity). The program treats two categories of sediment:

- No cohesive, which is referred to as sand herein and
- Cohesive which referred to as clay.

Either steady state or transient flow problems can be analyzed. The exchange of material with the bed can be calculated. Default values may be used for many sediment characteristics or these data values may be prescribed by input data. Theoretical basis: The derivation of the basic finite element formulation is prescribed in (Ariathurai *et al*., 1977) and summarized below. These are the major computation:

- Suspended sediment concentration using convection-diffusion equation with a bed source term,
- Bed shear Stress

$$\frac{\partial C}{\partial t}+v_x\frac{\partial C}{\partial x}+v_y\frac{\partial C}{\partial y}=\frac{\partial}{\partial x}\left(D_x\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_y\frac{\partial C}{\partial y}\right)+\alpha_1 C+\alpha_2 \quad (4)$$

With:

C	:	Sediments concentration in (kg m^{-3})
v_x,v_y	:	Flow velocity in (m/s)
D_i	:	Diffusion coefficient in (m^2/s)
α_i	:	Source term (1/s)
t	:	Time(s)

APPLICATION AND RESULTS

Steps followed: For the main basin of the mixed harbour the hydrodynamic situation was simulated, using the RMA2 model. The state of sedimentation is verified using the simulation module SED2D. To simulate the rather sophisticated bathymetry a combined triangular/quadratic mesh with element seizes from 2 to 320 m^2 with an overall of 1041 elements (Fig. 2) was applied.

The falling velocities (Table 4) were determined in function of granulometric values using the Stokes equation and an empiric formulation developed by U.S. Inter-Agency committee on water resources (Van Rijn, 1993).

Fig. 2: The calculated finite element mesh

Table 4: Falling velocities of sediments

d_{50} (mm)	Ws (m/s)
0.1	0.007
0.18	0.00015

Table 5: The quantity of dredged sediments

Zone	Orientation	Volume of sediments	Volume of sediments
Zone	Orientation	(in m^3)	(in m^3/year)
1	North	2156	10002
	Centres	3250	19214
	Southern	1550	20136
2	North	580	23540
	Centers	1233	32130
	Southern	325	17580
Total		9094	122602

Analysis of the various areas in mixed harbour in Skikda shows considerable differences in sedimentation distribution (Table 5). There is a shift of sedimentation to the south. In addition, increased inflow and outflow velocities and suppressed entrance vortices prevent significant amounts of silt from sedimentation.

CONCLUSIONS

The aim of this research is the study of the silting and the vase pollution in harbours. The selected study zone is the Skikda port. Seasonal samples were realized and chemical analysis, as for heavy metals contamination was undertaken. The analytical results were carried out using software Géodrisk. Within the analysed heavy metals, it was noted that mercury presents a high contamination risk. In other terms, the immersion in the harbour must take into account a detailed impact study. Analysis and simulation of flows and sedimentation into harbours basin of the port of Skikda shows that: Major sediment intrusion occur during high discharge superimposed on the tidal flows. A total of over 122.602 m^3 of sediment induced into the harbours basin per year and the most intense sedimentation takes place in the central part of the harbour basin with annual amounts ranging from 1233 to 3250 m^3. It has to be noted that other simulations using the above mentioned software are necessary and this is used to make decision on the localization of the silting areas.

The latter's need targeted bathymetric measurements. Lastly, the use of SIG, allows without any doubt the acquisition of the given data which naturally enhance having in, place innovating devices which validate the value of obtained data in the laboratory.

REFERENCES

Ariathurai, R., R.C. Mac Arthur and R.B. Krone, 1977. Mathematical Model of Estuarial Sediment Transport. Technical Report D-77-12, US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Miss.

Alzieu, C.L., 1999. Dragages et Environnement Marin: Etat des Connaissances. Editions Ifremer, 29280 Plouzané (F), 224 p. No. HY11, 1973.

Hocini, N. and M. Mami, 1991. Application of radioactive tracers to the sand deposition in of the new harbor of Skikda. Preliminary report (Nuclear techniques development Center).

Quiniou, F., A. Judas and et Le Squer-André, 1997. Toxicité potentielle des eaux des sédiments des principaux estuaires de la rade de Brest évaluée par deux bioessais. Ann. Inst. Océanogr, Paris, 73: 35-48.

Robbe, D., 1989. Stratégie d'évaluation-échelle spatio temporelle, relation entre les sites d'immersion et les zones de sédimentations. Actes du séminaire international sur les aspects environnementaux liés aux dragages. Nantes, pp: 335-346.

Roig, L.C., B.P. Donnell, W.A. Thomas, W.H. McAnally and S.A.Jr. Adamec, A Users Manual for SED2D-WES, A Generalized Computer Program for Two Dimensional, Vertically Averaged Sediment Transport. US Arm.

Van Rijn, L.C., 1993. Principles of sediment transport in rivers, estuaries and coastal seas. Aqua Publications, Amsterdam, Niederlande.

Schwarze, H. and K.D. Müller, 1995. Some Studies to Reduce Sedimentation in a Port on a Tidal River. Water Science Technology, Vol. 20, No 6/7, 1988. Schwarze, H., C. Zimmermann and G. Streich, Reduction of Sedimentation in Harbour Entrances on Tidal Rivers by Modification of the Entrance Geometry and Installation of Stream Guiding Structures. Proceedings of COPEDEC IV, Rio de Janeiro.

US Army Corps of Engineers, 1997. Users Guide to RMA2 WES Version 4.3. US Army Corps of Engineers, Waterways Experiment Station-Hydraulics Laboratory, Vicksburg, Miss.