Pressure and state of the marine chemical contamination in the vicinity of a large coastal Mediterranean city, the case of Marseilles

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Keywords: Marseilles, pollution flow, contaminant inputs, wastewater, storm water run-off, modelling

Abstract

Marine pollution is one of the priority issues of the Mediterranean environment. This pollution comes from multiple sources including large coastal cities which are considered as hot-spots. The METROC project objective is to assess gross and net chemical contaminant flows related to large Mediterranean coastal cities, with a first application to the Marseilles area. The methodology consists of i) assessing the present state of the chemical contamination of the coastal environment; ii) assessing inputs to the sea from sewage, small rivers and storm water run-off; and iii) modelling the fate of some key contaminants, in order to attempt to establish a balance between inputs and exports towards the open sea. This short article presents a synthesis on these different phases.

Résumé

La pollution du milieu marin est l'un des problèmes prioritaires pour l'environnement méditerranéen. Cette pollution provient de multiples sources en particulier de grandes citées considérées comme des "points chauds". Le projet METROC a pour objectif d'évaluer les flux bruts et nets des contaminants chimiques issus des grandes métropoles côtières méditerranéennes en prenant comme premier cas d'application l'agglomération marseillaise. La méthodologie consiste à : évaluer l'état actuel du milieu marin ; évaluer les apports au milieu marin en provenance des rejets industriels et urbains, des cours d'eau côtiers et des déversoirs d'orage ; puis à modéliser le devenir de quelques contaminants clefs pour lesquels on tentera d'établir un bilan. Ce court article présente une synthèse des différentes phases du projet.

INTRODUCTION

Marine pollution is one of the priority issues of the Mediterranean environment. This pollution comes from multiple sources. The Mediterranean Action Plan has shown that few large cities were responsible for a major fraction of the inputs from urban areas and should be considered as hot spots. The METROC project objective is to assess gross and net chemical contaminant flows related to large Mediterranean coastal cities, with a first application to the Marseilles area. It comes from an Ifremer initiative and is supported by the Rhone Mediterranean & Corsica Water Agency, territorial communities and scientific partners. Methods consist of i) assessing the present state of the chemical contamination of the coastal environment; ii) assessing inputs to the sea from sewage, small rivers and rain water run-off; and iii) modelling the fate of some key contaminants, and establish the balance between input and export towards the open sea. This short article presents a synthesis on these different phases and their results.

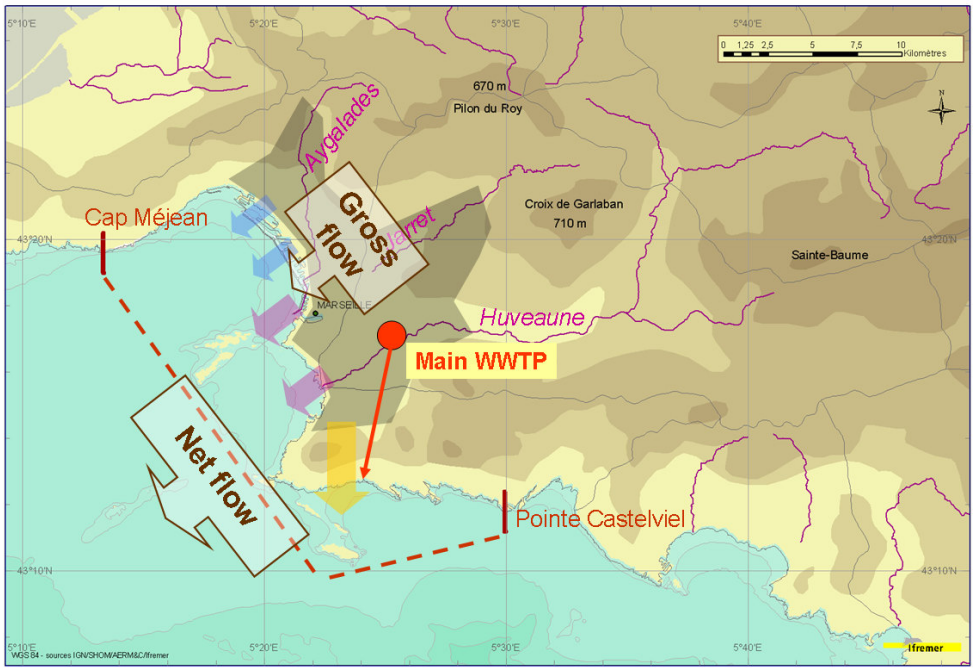

Figure 1. Pollution flows from the agglomeration of Marseilles, general map

The area under study is the Gulf of Marseilles, directly impacted by the chemical contamination inflows resulting from the Marseilles urban agglomeration (Fig. 1). These inflows concern mainly:

- Discharges of the sewerage network, which drains the domestic and industrial wastewater;
- The semi artificial water courses and untreated storm water drain outlets;
- Effluents of the main sewage system which are treated by a primary and secondary large wastewater treatment plant (WWTP), with a capacity of 1.8 million equivalent inhabitants This WWTP serves 16 communities consisting

of over one million inhabitants, for a total surface of about 520 km².

Water courses are primarily coastal rivers whose watersheds cover 560 km². The urban area is bordered by the Mediterranean on its Western frontage with a linear coast length of 50km (outside the islands). On the landside, the Gulf of Marseilles includes three principal sectors:

- The strongly urbanized northern harbour, with industrial and commercial facilities related to port activities;
- The southern harbour, urbanized with balneal activities, which receives the natural flow of the main river, Huveaune, only flowing during storm condition;
- The southern seafront with a very steep relief, which receives in the Cortiou creek both the main WWTP outlet and the Huveaune river flow in normal condition.

The continental shelf is narrow in this sector and the depth in the Gulf increases to reach 100 meters close to its outside limit.

METHODOLOGY

The general objective of this study consists in evaluating gross and net flows of chemical contamination stemming from the agglomeration of Marseilles. Gross flows are those which arrive to the sea, net flows are those which are exported offshore from the coastal zone and which feed the general contamination of the Mediterranean basin. The method consists of:

- Establishing a diagnosis of the marine environment chemical contamination. The contaminants in biota, sediment and in some cases water are measured, with complementary work using passive samplers;
- Measuring the land-based contributions in contaminants, by carrying out a sampling campaign in order to characterize these contributions for various weather situations (dry and rainy time) by distinguishing dissolved and particulate fractions;
- Modelling the fate of these contributions, by using 3D coupled models including an hydrodynamic model for the dissolved fractions and, a sediment transport model for the particulate fractions;
- Establishing assets of contaminant flows from the results of these models.

MARINE COASTAL CONTAMINATION STATUS

A campaign of surface sediment sampling with a box corer was carried out in November 2004, including 42 points, located on radials over a distance of about 15 km.

For biota, the active biomonitoring technique was used: mussels from a common origin were transplanted into oyster bags attached to buoys and installed for a

period of about three months. Contaminants were measured in the whole flesh of mussels. 15 stations were placed on radials at 20, 40 and 70 m water depth.

Approximately, the same set of contaminants was measured in sediment and mussels:

- Metallic: Pb, Cd, Hg, Ni, and Al;
- Organic: 16 PAHs, DDT, DDD and DDE, CB 138 and CB 153 and, in mussels only, dioxins and furans.

In addition, following work was done:

- A campaign using experimental passive samplers;
- Ecotoxicological tests (oyster larvae test) on the sediment (35 points);
- Experimental measurements on emerging contaminants (akylphenol, polyethoxylates and pharmaceuticals) in the discharge plume of the principal urban outlet;
- The results were compared with previous studies. Maps of contamination were established, such as in Fig. 2 and Fig. 3. Results showed contrasted levels of contamination:
    - strong for lead, with very high levels (573mg/kg) in the area of Cortiou and, to a lesser extent, in other areas of the Gulf
    - significant for mercury, PAHs[1], DDT, and PCBs[2]
    - localized for dioxins and furans, as well as for emerging contaminants.

All of these results are presented in Sauzade *et al.* 2007.

[1] PAHs: Polycyclic Aromatic Hydrocarbons
[2] PCBs: Poly Chlorinated Biphenyls

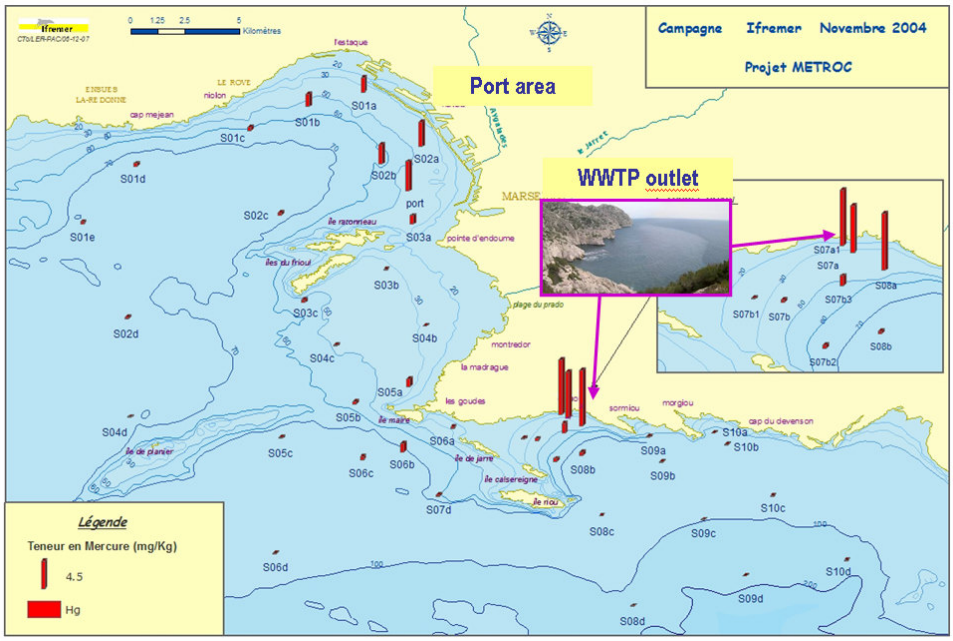

Figure 2. Mercury levels in superficial sediment

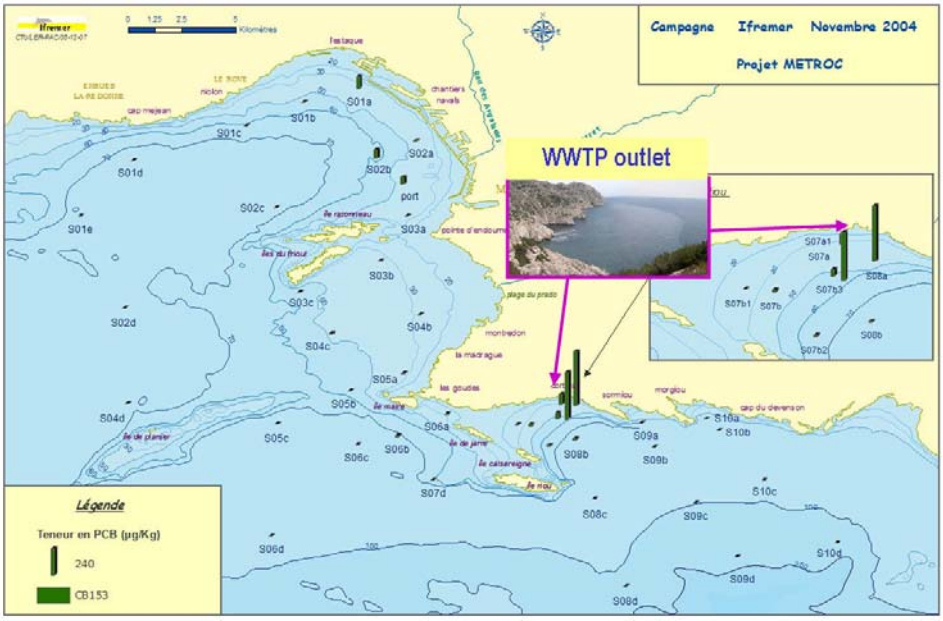

Figure 3. PCB levels in superficial sediment

ASSESSMENT OF INPUTS

The assessment of inputs to the marine environment is particularly difficult due to the number and diversity of inputs and the rapidly changing discharge patterns, strongly depending on flow rates during rainy periods. With the help of the Water

and Sewerage Department of the Marseilles Provence Metropole Community Council[3] and the operating company SERAM, a sampling program is being defined.

A minima, it will include i) for dry weather condition, a sampling point in front of the wastewater treatment plant, a sampling point on each of the two largest coastal rivers; and ii) for wet weather condition, the same points plus two points on storm water drains.

Measurements of suspended matter (SM) and contaminants will be reported to concomitant water flows. Many previous measurements made for various weather patterns show that the annual flow of water is about 2,107 m^3, approximately half of which is processed by the wastewater treatment plant. Wet weather only accounts for 10% of the water flow but nearly 80% of the SM contribution (Le Masson, 1997).

Chemical contaminants selected for the first assessment of the flow are:

- Metal contaminants: Pb, Hg, and Ag
- Organic contaminants: PCBs, PAHs, and PBDEs[4]

MODELLING THE FATE OF CONTAMINANTS IN MARSEILLES COASTAL WATERS

The fate and bioavailability of contaminants in the marine environment are governed by various biological, chemical and physical processes. For a contaminant, the predominance of one of these processes will depend mainly on physico-chemical and contaminant variables (physical, chemical and biological) and environmental variables (current velocity, concentration and nature of suspended matters, concentration and nature of organic matter, sedimentation rate, *etc*.). These parameters are either known or modelled by a hydrodynamic and sediment model, supplemented by a biogeochemical model of organic matter recycling.

A 3D hydrodynamic model using MARS 3D (André 2005) is being validated (Fig. 4.) and a transport model of suspended matter is under development. Their calibration and validation require multiple measurements (current velocity, salinity, temperature, sediment altimetry, suspended matter concentration, sediment surface erodibility).

[3] Communauté Urbaine Marseille Provence Métropole
[4] PBDEs: Poly Brominated Diphenyl Ethers

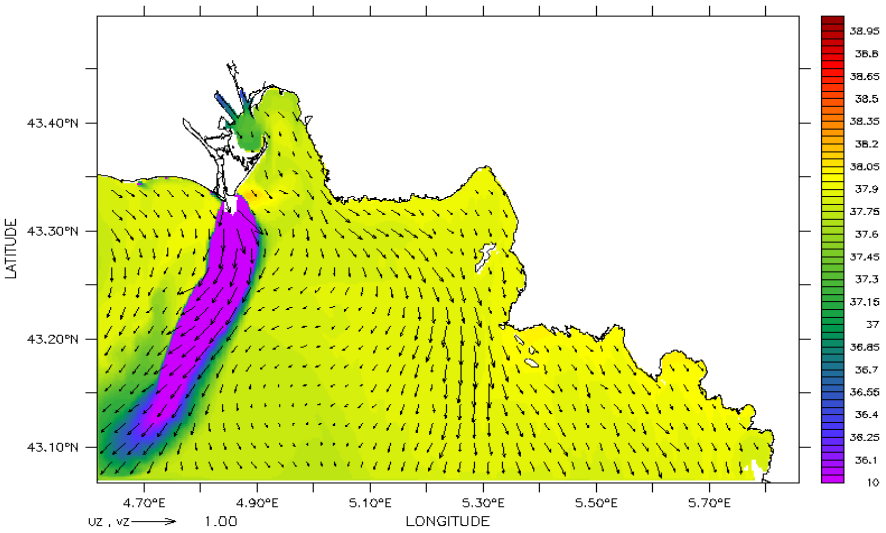

Figure 4. Rhone river mouth-Marseilles MARS 3D model output. Surface salinity (PSU) and currents, situation of strong northern wind (27-sep-2007)

The chemical dynamics model for selected contaminants is being defined. It will then be coupled with the previous models to build the final model of contaminant fate.

BALANCE OF THE CONTAMINANT FLOW

These models will make possible to compute balances between gross flows (incoming) and net flow (exported) for selected contaminants in homogeneous areas of the study site. Results will be compared with the marine environment status established in previous phases. The various sources of contaminants (effluents, rivers, runoff, and atmospheric deposition) will be ranked. Importance of different climatic conditions will be evaluated. A comparison with other known sources of contaminants to the north western Mediterranean (like the Rhone river contribution for instance) basin will be attempted. If realistic, these models can be used at a later stage to consider scenarios, depending on various assumptions such as decrease or increase in contaminants inflows.

CONCLUSION AND PERSPECTIVE

The METROC project for the assessment of gross and net flows of chemical contaminants from a large coastal city, Marseilles, began in 2003. Six years later, results have been obtained in terms of marine environment status, knowledge of inflows, modelling (hydrodynamics, suspended matter, fate and transfer of contaminants). These results also enabled to provide expertises for the benefit of territorial communities which support this project. Preliminary contaminant flow balances are expected for 2012. The long duration of this project is mainly due to

its innovative parts, but the experience gained in the Marseilles case study should shorten and make easier further applications to other major Mediterranean coastal cities.

ACKNOWLEDGMENTS

This project was possible thanks to the support of the Water Agency of Rhone Mediterranean & Corsica. It also received the support from the managers of the City of Marseille, the Marseilles Provence Metropole Community Council and the concerned State administrations. It also fostered several scientific collaborations, especially with the Center of Oceanology of Marseille.

REFERENCES

Andral B., Stanisière J.Y., Sauzade D., Damier E., Thébault H., Galgani F., and Boissery, P., 2004. Monitoring chemical contamination levels in the Mediterranean based on the use of mussel caging. Marine Pollution Bulletin 49: 704-712.

André G., Garreau P., Garnier V., and Fraunié P., 2005. Modelled variability of the sea surface circulation in the North-western Mediterranean Sea and in the Gulf of Lions, Ocean Dynamics 55: 294-308.

Arfi R., Arnoux A., Bellan-Santini D., Bellan G., Laubier L., Pergent-Martini C., Bourcier M., Dukan S., Durbec J.-P., Marinopopoulos J., Millot C., Moutin T., Patriti G. and Petrenko A. (V. de Marseille), 2000. Impact du grand émissaire de Marseille et de l'Huveaune détournée sur l'environnement marin de Cortiou - Etude bibliographique raisonnée 1960-2000. 137 pp.

European Environment Agency, 2006. Priority issues in the Mediterranean environment. 88 pp.

Le Masson J. et *al*., 1997. Mesure de la pollution par temps de pluie à Marseille, Rapport SERAM pour la Direction de l'Assainissement de la Ville de Marseille, 21pp.

Sauzade D., Andral B., Gonzalez J.L., Galgani F., Grenz C., Budzinski H., Togola A., Lary S., Kantin R., and Cadiou J.F., 2007. Synthèse de l'état de la contamination chimique du golfe de Marseille, Rapport Ifremer DOP/LER-PAC/07-05 pour l'Agence de l'Eau Rhône Méditerranée & Corse, 209p.

Strazzulla J.Y., 1985. Bilan de la contamination chimique des sédiments du golfe de Marseille (thèse).

UNEP/WHO, 2003. Second Report on the pollution hot spots in the Mediterranean-Part II-Revised Country Reports. Meeting of the MED POL National Coordinators, Sangemini Italy, 27–30 May 2003. UNEP (DEC) MED WG.231/5b.

Wafo E., Sarrazin L., Diana C., Schembri T., Lagadec V., and Monod J.L., 2006. Polychlorinated biphenyls and DDT residues distribution in sediment of Cortiou (Marseille, France) Marine pollution bulletin 52: 104-120.