Calculation of the loads of chronic pollution from roadways runoffs

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Abstract

Motorway infrastructures may cause a chronic pollution of water resources. Wear residues from vehicles, coatings, road equipment as well as the emissions from road vehicles induce an accumulation of particles upon the carriageway which are swept from the roads each time it rains. Protection of the water resource, defined as the common heritage of our nation (Art. L210.1 Code de l'Environnement), requires appropriate measures. To comply, first it is necessary to know about the loads of pollutant which are deposited upon the carriageway to assess the works suited for the protection of the water resource. The National Technical and Scientific Network of the Ministry of Equipment have exploited the measurement provided at nine equipped locations.

The goal of this operation was to obtain correlations between the actual loads in the runoff, concerning various pollutants (suspended matter, PAH, COD, lead, zinc, cadmium, copper and hydrocarbons), and various parameters (annual precipitation, maximal intensity of the rain event, traffic, number of days of dry weather, etc.). At present, two relations might be applied:

- a pollution/traffic law linking the total traffic and the maximal annual global load of pollution collected in the runoff;
- a law linking the maximal compound fraction of annual pollution swept along, and the height of water of the associated event.

These two laws make it possible to quantify the chronic pollution that therefore is liable to reach the water resources and then to adapt the strategy of water resource protection according to the sensitivity of the aquatic environment.
Keywords: runoff, infrastructure impact assessment, copper, cadmium, suspended matter.

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1 Context

The examining authorities of the impact assessment of the road infrastructures' projects are very attentive about chronic pollution due to roadway runoffs: sometimes the decrees of authorization are taken without considering the real impact on the water resource. The data which are still used as a reference date back more than 25 years: at this time gasoline contained lead, only a few vehicles used gas oil, engines were less powerful, were more prone to oil and water leaks and generated more pollutants (lead, hydrocarbons) particularly harmful to the environment. Today lead has almost totally disappeared from fuel: the measured values are, in the majority of the cases, under the levels decreed safe for drinking water [15]. It is not taken account in this paper. Theoretically the precious metals (platinum, iridium, rhodium …) used as catalysts in the mufflers, would have also had to be considered as metal elements. Nevertheless, regarding the latest technologies (the new monolithic catalysts reduce this platinum emission of a factor 100 to 1000) [8], the contents likely to be reached are extremely slight (under detection limit) and will not be considered in this analysis. With this purpose, the results of the long duration measures carried out in the period 1995-2005 on various motorways distributed through the whole national territory have been exploited. It appears that it was not possible to obtain, from these measures, regional values. On the other hand "Pollution-Traffic" laws could be established. Moreover, to take into account the fact that an important part of the pollution emitted is not taken up by the storm water drainage systems, but projected into the nearby surroundings, a distinction has been made between open site (no obstruction for the dispersion by air) and limited site (the pollution accumulate more on the road because of obstructions for the dispersion by air).

2 Methodological process

The data taken into account in the former document [1] came from various studies realized up until 1987. At that date several experimental sites had been equipped so as to characterize the chronic pollution resulting from road exploitation. These sites placed on the interurban motorways (A1, A4, A6, A61, A2, A11, A10, A26) had been distributed through the whole French territory. These sites have been reactivated and new sites were placed so as to update the data, taking into account the evolutions concerning the traffic, the composition and the quality of the fuels, and the improvement of the workings of vehicles.

A relationship between global pollution load and traffic is underlined and may be retained. The traffic taken into account is the AADT (annual average daily traffic).

In other aspects the studies have shown that the polluting loads could differ for the same traffic according to the presence, or not, of obstructions for dispersion by air. Chronic pollution mentioned in this paragraph concerns: link sections, toll plazas, interchanges, and other areas.

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2.1 Definition of open and limited sites

An open site corresponds to an infrastructure, the outskirts of which do not oppose the dispersion by air of the polluting load. A limited site corresponds to an infrastructure, the outskirts of which limit the dispersion by air of the polluting load. These screens that limit dispersion have a minimal length of 100 m, a height equal to or more than 1,50 m, and are placed on each side of the infrastructure, face to face. They are defined thus: noise barrier, earth bank, retaining wall, safety devices, cutting slopes. Plantations (hedges, trees) are not considered as “screens”. The impermeable surface for the loads corresponds to the whole soil surface covered with hydraulic or bituminous concrete, or with double surface dressing, or geomembrane. The surfaces to take into account are those: of the carriageway, of the coated verges or pavements, of the central reservation, of the lay-by, and of the toll platform.

2.1.1 Annual polluting loads drained by the runoff

Link sections:

The Unitarian annual polluting loads to take in account are, for the carriageways, not constituted with porous asphalt, as follows.

Table 1: Unitarian annual polluting loads Cu for one impermeable hectare and 1000 veh/day.

Unitarian annual polluting loads Cu For one impermeable hectare and 1000 veh/day	Suspended matter kg	COD kg	Zn kg	Co kg	Cd g	Hydrocarbons g	PAH g
Open site	40	40	0,4	0,02	2	600	0,08
Limited site	60	60	0,2	0,02	1	900	0,15

For global traffic under 10 000 vehicles per day, the annual polluting loads are calculated proportionally: to the global traffic and to the impermeable surface

$$\mathbf{Ca} = \mathbf{Cu} \times \frac{\mathbf{T}}{\mathbf{1\,000}} \times \mathbf{S}$$

Figure 1: Equation 1: annual load for traffic under 10 000 veh/day.

T = AADT (Annual average daily traffic)
S = impermeable surface (ha)
Cu = Unitarian annual polluting loads for one impermeable hectare and 1000 veh/day

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For traffic over 10000 veh/day: the observation shows that beyond 10000 veh/day the increasing of the polluting load weakens. The annual load is given as follows:

$$\mathbf{Ca} = \left[(\mathbf{10} \times \mathbf{Cu}) + \mathbf{Cs}\left(\frac{\mathbf{T - 10\ 000}}{\mathbf{1\,000}} \right) \right] \mathbf{S}$$

Figure 2: Equation 2: annual load for traffic over 10 000 veh/day.

Cs = Specific annual polluting loads for one impermeable hectare and 1000 veh/day over 10 000 veh/day

The specific annual polluting loads to take in account are, as follows.

Table 2: Specific annual polluting loads for one impermeable hectare and 1000 veh/day over 10 000 veh/day, for open and limited sites.

Specific annual polluting loads for one impermeable hectare and 1000 veh/day over 10 000 veh/day	Suspended matter kg	COD kg	Zn kg	Co kg	Cd g	Hydrocarbons g	PAH g
Cs	10	4	0,0125	0,011	0,3	400	0,05

During an impact assessment, the calculation of the annual polluting load must be carried out retaining the following traffic:
- for new infrastructures: the traffic foreseen 15 years after the startup
- for existent infrastructure: the traffic foreseen 10 years after the installations of protection of the water resource.

2.2 Particular cases

2.2.1 Toll plaza
The annual polluting load of a toll station is determined according to its visiting traffic and to its total surface between the link sections. It is convenient to retain the characteristic values of a limited site.

2.2.2 The interchanges
The annual polluting loads on interchanges are calculated from: the traffic on the interchange and the impermeable surface of the interchange.

2.2.3 The areas
The annual polluting loads for a rest, or a service area, depend on: the traffic of the link section, which serves the area and the impermeable surface. For a two-

way area the global traffic is taken in account. For a one-way area, only the traffic of the circulation direction which feeds the area is taken in account. If the traffic data according to circulation directions are not available, the traffic attributed to one direction is equal to half the global traffic. The annual global polluting loads are equal to 1/10 of annual global polluting loads established for link section in limited site. Waste water and water associated with the washing services offered on the area produce a polluting load that must be estimated in more of the chronic polluting loads and treated in accordance with the regulation in force. Very often, the polluting loads linked to the services are quite a lot higher than those characterizing the chronic pollution.

2.3 Maximal impact of runoff

Experimentation has shown that the maximal impacts are by a summer rain in a low water period. The winter polluting loads are therefore not taken in account. The measures from experimental sites have likewise shown that the peak event is directly linked to the volumes of rain that generate this peak event. The relation is established as follows:

$$\mathbf{Fr} = \mathbf{2{,}3} \times \mathbf{h}$$

Figure 3: Equation 3: maximal fraction of annual polluting loads swept.

h = precipitations (m)

The runoff impact is due to its concentration and the capacity of the water resource to endure a concentration increasing which does not impair its use or its vocation.

The runoff quality must be compatible with the aims and measures defined in the impact assessment, namely:

- uses of water resource (drinking water supply, pisciculture, bathing place);
- the qualitative aims of national laws and decrees;
- the sensibility of the aquatic ecosystems;
- the aims of Framework Directive in the field of water policy [10, 12–14].

Table 3: Quality aims of Rhône drainage basin.

Aims/ Maximal concentration	1A	1B	2	3
Suspended matter (mg/l)	25	25	70	150
COD (mg/l)	20	25	40	80
Co (µg/l)		5	1000	
Cd (µg/l)	2	5	5	

1A corresponds to a quality that allows any use of surface water.

$$Ce = \frac{Fr\ Ca\ (1-t)}{10\ S\ h} \quad \text{or} \quad Ce = \frac{2{,}3\ Ca\ (1-t)}{10\ S}$$

Figure 4: Equation 4: runoff concentration during a peak event (mg/l).

Ca = annual loads (kg)

Finally, during the peak event, the maximal concentration depends only on the traffic.

2.4 Average concentration of storm water runoff

The pollution drained by the rain is characterized by chronic phenomena and sharp ones constituting a peak event that appears once a year (maximal impact notion introduced in the former paragraph). This average concentration (Cm) is calculated as follows:

$$Cm = \frac{Ca\ (1-t)}{9\ S\ H}$$

Figure 5: Equation 5: average concentration (mg/l).

S = impermeable surface (ha) surface imperméabilisée en ha
H = annual precipitations (m)
t = efficiency of water protection works

In the specific hydrographic areas (annual average precipitation < 500 mm), no observation could be realized. The Precipitation value retained for the concentrations calculations is then 500 mm.

3 Road runoff evolutions

It can be interesting to compare the new results with the old data:
This example shows a project of 3 impermeable hectares:

Table 4: Concentration during peak event with former data.

Concentration during peak event	Suspended matter mg/l	COD mg/l	Zn mg/l	Co mg/l	Cd µg/l	Hydrocarbons µg/l	PAH µg/l
5000 veh/day	150	140	1,4	0,1	7,1	2700	0,35
35000 veh/day	1050	980	9,6	0,7	50,1	19000	2,45

Table 5: Concentration during peak event with new data.

Concentration during peak event	Suspended matter mg/l	COD mg/l	Zn mg/l	Co mg/l	Cd µg/l	Hydrocarbons µg/l	PAH µg/l
5000 veh/day	46	46	0,46	0,023	2,3	690	0,092
35000 veh/day	149,5	115	0,92	0,15	6,3	3680	0,4715

As we can see, the polluting loads have dropped since 1987 with a factor from 2 to 10. However, it is noted that pollution, in particular in term of COD, remains largely above the sensitivity of certain aquatic environments. The levels of cadmium and suspended matter are also above the acceptable thresholds. However, the most risk is with respect to the COD: indeed, the COD is the pollution most difficult to treat by the traditional works.

4 Conclusion

The new data thus confirm that pollution has significantly decreased since the year 1980. The motorway levels remain, in particular, dangerous because of the presence of metal element traces, and of suspended matter suitable to asphyxiate the ecosystems. The motorway runoffs thus require to be treated starting from 3000 vehicles per day traffic. This new method however makes it possible to obtain a technical answer adapted to the risk incurred to the aquatic environment. Moreover, the new qualitative aims related to the transcription of the DCE will impose a finer knowledge of the priority substances present in the motorway runoffs. This is why, the sites given up since 2005 will be given back in service in the next years: on the one hand, in order to follow the evolution of the quality of the runoffs, and in addition, in order to identify a finer relationship between the pollution and the climate.

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