SENSORS FOR WASTE WATER : MANY NEEDS BUT FINANCIAL AND TECHNICAL LIMITATIONS

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1. Introduction

A waste water system can be divided into three steps, from upstream to downstream, according to different responsibilities of operation :

- discharge of waste water in the sewer, especially industrial discharge
- collecting network (combined or separate) and combined sewer overflows
- waste water treatment plant and discharge of epurated water in receiving water.

We will examine separately the needs at the above three levels as well as the current practice, because they are very different when considering them technically, financially or legally.

Most of the online measurements are performed after treatment or pre-treatment in order to check compliance with a predefined consent level. Recent environmental directives in EEC are pushing in parallel the various ways of measuring water quality : laboratory analysis, field instruments and online monitors, especially at discharge level.

However online monitoring is now also expanding in control system for the automatic or man assisted operation of the water works.

2. Present level of equipment

If we let aside flowrate measurement and level measurement, online monitors are still rare in waste water systems, especially in collecting sewers. This is in relationship with the size of the collecting networks, and with the fact that this subterranean part of the system is ignored by most of the people.

For the various agents in water field - private or public operators, communities, river authorities - it is different. Due to historical reasons, and because everyone is reluctant to change his own habits, control and operation of waste water systems are mainly based on sampling and laboratory analysis.

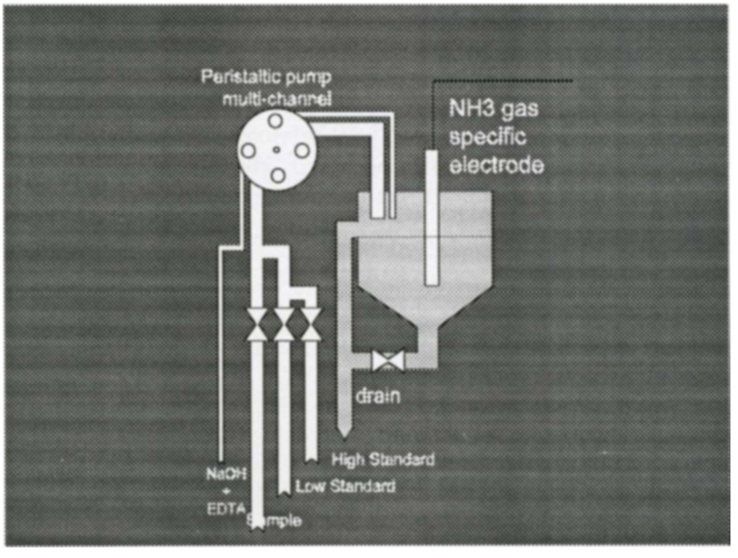
Figure 1 : analysers parts

ELECTRONICS	Traditionally, an automatic analyser can be divided into three parts :
HYDRAULICS	The with electronic components are located at the top, a screen and a keyboard.
REAGENTS STORAGE	The pumps and piping are in the middle part, generally behind a glass door The lower compartment is for reagents storage.

Online monitors are rarely considered, though they show nice features such as :
response time : a few seconds or a few minutes instead of a few days.
time covering : the overall yearly period is covered, which is not ordinary the case with daily samples.
automation : from sampling to result presentation, every step is automatic. This allow for automatic reaction of the system to adjust to new conditions or automatic warning of the human agent.

At the level of a discharge into the public network, main industrial sites or most pollutant ones are progressively obliged to install online monitoring of water quality. They often start with flowrate measurement and automatic sampling, then temperature, pH, conductivity, O2 or rH. In some case they follow with TOC monitor, which is much more expensive. According to our information, about 500 TOC monitors are installed in France on industrial discharges in order to follow up organic pollution load.

Figure 2: automatic analyser for ammonia using gas electrode

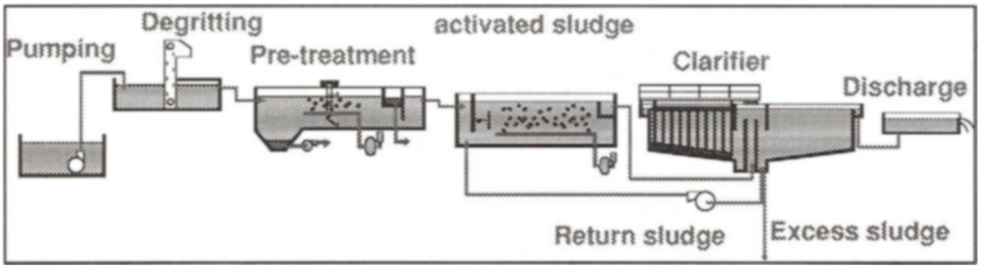


In collecting network, online instrumentation is very poor, in almost every case it concerns level or flowrate measurement. The reason is that flow is made by gravity, there is no need and no way to adjust the flow and for the same reason it is not necessary to measure it except in pumping stations. But things are changing, because of the public concern about Environment and water quality.
Public authorities are imposing tougher and tougher checking especially at overflows, which are very numerous and responsible for a large part of pollution during rainfall events in combined systems. Continuous monitoring of collecting network is encouraged, level detectors are installed in overflows, in some cases they are completed by flowrate measurements, automatic sampling or quality measurements such as turbidity, dissolved oxygen, ect ...

Online instrumentation is not yet common at the inlet or the discharge of waste water treatment plants. A recent enquiry from AGHTM (the French Professional Water association) and not yet published, has shown that online sensors are almost non existent in present plants under 50 000 PE and represent only a few percent in bigger ones.

For process control, inside the plant, online sensors are less rare, about 4 percent of the plant have at least one sensor. If we except flowrate or level measurements which are rather common, in the water file we could find mainly sensors for dissolved oxygen or O.R.P. in activated sludge. In some occasion they are completed by TSS at the inlet, after primary settling tank, in activated sludge or return sludge or return mixed liquors, and sludge blanket level in settling tanks. In the sludge file we could find sludge blanket level in thickeners, TSS at various steps, pH and temperature in digestors, sensors related to air quality and staff security (CH4, NH4, explosion index, etc...).

Figure 3 : waste water treatment plant, low rate activated sludge



3. Regulation as a support to online monitoring.

In France, industrial wastes are driven by the ministerial order dated 01 March 1993, to be modified in a next future. This order gives a limit value for every parameter related to organic pollution (COD, BOD, TSS ...etc.) but also for various other pollutants more specific of industrial activity. It is well known that some organic or mineral by-products of industrial activity are non biodegradable or have a toxic effect, sometime very far from the emission point.

This is the case of heavy metals in particular, which are concentrated in the activated sludge of waste water treatment plants or in the sediments of the rivers or along the biological chain in the ocean.

The French ministerial order dated 22 December 1994 is related to monitoring waste water systems. It uses the parameters defined in EEC directive dated 21 May 1991, that is to say COD, BOD, TSS and over that total Nitrogen and total Phosphorus for sensitive areas. The frequency of analysis for every parameter is defined according to the size of the system : it varies from 4 to 365 analysis of daily samples per year, that is to say once a day.
The means of measurement are not specified, by default it is laboratory analysis, so to substitute it by online monitoring a preliminary agreement must be found with the various administrations in charge of water quality control.

The alternative of continuous monitoring is suffering from a lack of credibility in public institutions. This comes from the fact that a new parameter always comes with a standard referring to laboratory analysis, in order to define how to measure it. Continuous measurement comes later on, and naturally it differs slightly ore deeply from this standard protocol. Therefore online measurement is suspected to lead to a second choice measurement compared with laboratory analysis.

For instance a satisfactory operation percentage of 60 % of the time is often met for an automatic analyser, which is disappointing for the end user or not admissible for a control loop. A high educational level , intensive maintenance and cleaning are often required, and this is not always adequate with the existing staff which is not as specialised and numerous as in an industrial plant.
There are not enough standards and specifications to guarantee a predefined level of quality for online monitoring, so that both the user and the administration can rely on online monitoring. A project named ETACS, supported by EEC commission DG XII, has the objective to produce a pre-normative standard protocol for the evaluation of waste water quality analysers.

4. Technical aspects of continuous measurement.

There are many ways to associate an instrument and a process line : the instrument can be in line, on line, at line, off line. The instrument itself is not alone, it is a link in a measuring chain which has many other links :

- sampling and transfer of the sample,
- division of the sample, a fraction is taken and transferred again,
- conditioning of the sample before analysis
- analysis of the sample, in a single step or after several steps
- electrical output, transfer, data is digitised, processed and presented to the user

Referring to industrial waste monitoring, useful parameters are very numerous. The basic ones are TSS, COD, TOC and BOD.

The other ones are very specific of every activity and even every site : heavy metals are common in surface treatment and mechanical industry, chromium in tanneries, oil in petrochemical industry, AOX, PCB in industries using chorine. An other aspect which is a challenge for online monitoring is the complex meaning of toxicity. In some cases, it is very important to appreciate continuously and rapidly the risk of releasing a waste in a biological system located downstream.
This starts often by introducing the waste in the treatment plant itself, because it is very often based itself on biology. On an other side water like other elements follows a cycle which includes many successive uses along the watershed, and a part of it becomes drinking water for human communities.

In collecting networks, needs of online monitoring are concentrated in overflows, and they are similar to those related with discharge into waste water treatment plants. Once again basic parameters are COD, BOD and TSS, with total N and total P in sensitive areas. Technical constraints are stronger in a sewer, the accessibility is bad, the space is limited, and environmental conditions are not favourable to instrumentation (humidity, darkness, flooding, strong variability of flow, detritus of all size in water ...etc.).
The network itself is large, so it cannot be monitored at every node, a hierarchy of the needs must be set. When starting from nothing, which is generally the case, some parameters are already accessible online and are not too costly, such as turbidity, pH, conductivity, dissolved oxygen, O.R.P. and organic load indicators.

At the inlet and at the discharge of a waste water treatment plant, the law has fixed the parameters to follow. Some of them are not accessible to online monitoring, some other are difficult or costly to measure online, but they can be derived from more accessible parameters, for instance turbidity to estimate TSS and COD, UV and visible absorbance to derive COD, NH4 and NO3 to derive total Nitrogen, PO4 to derive total phosphorus.

We still need automatic analysers measuring the imposed parameters :

- total phosphorus instead of PO4
- total nitrogen instead of NH4, NO2 and NO3
- COD instead of pollution indicators
- BOD or a substituted standard parameter
- TSS instead of turbidity

Table 1 : list of needed sensors and analysers in waste water systems

parameters	Exists?	Cost in kF	Comments on needed features
pH	+++	10	ruggedness, auto-cleaning, auto-calibration
rH	+++	10	automatic cleaning, prevention of contamination
O2	+++	15	automatic cleaning and automatic calibration
H_2S	++		analysis in sewers, very harmful
TSS at inlet	0	70	via turbidity, automatic cleaning of detritus, grease
TSS at discharge	0	25	low cost, auto-cleaning, without maintenance

parameters	Exists?	Cost in kF	Comments on needed features
sludge settlability	+		equipment derived from lab, too complex & costly
siccity of sludge	+		field test, not yet online instrument.
Sludge blanket level	+++	30	optical absorb. or U.S. reflection, need of auto cleaning and sensitivity
NH_4^+	+++	80	low cost, reliability, not too much maintenance
NO_3^-	+++	80	low cost, reliability, not too much maintenance
total nitrogen	++		too complex, too costly actually
PO_4^{3-}	+++	100	low cost, reliability, not too much maintenance
total phosphorus	0		not really available online, not effective
COD	++	200	derived from lab, low cost and reliability needed
BOD	++		far from standard (5 days)
TOC	+++	140	low cost, reliability, not too much maintenance
biodegradability	++		concept to be clarified and standardised
toxicity	++	to 400	standard, low cost, light maintenance, interpretation

Keys for Existence : +++ : well developed, ++ : need some " tuning ", + : still in infancy
0 : not yet available

For dewatered sludge, needs are specific : pH, siccity, mass and volume flow, biological stability index, odours, lime content, available fertilisers N and P, micro-pollutants such as heavy metals (Hg, Cr, Cd, Cu, Pb, Ni, Se, Zn), HAP and PCBs.

5. Conclusion

Technically, the needs of online monitoring are strong in order to operate and to follow up the waste water systems, but more than technical aspects, the lack of standards and the high cost are the mains reasons why online monitoring is not yet developed in waste water.

Today, the cost of a cheap sensor such as a pHmeter is less than 10 kilo Francs, and at the opposite, a toxicity analyser using respirometry or bioluminescence is more than 400 kilo Francs. And naturally, the owner's cost is not limited to simply buying the instrument. For instance the cost of an analyser for NH4, NO3 or PO4 is about 150 to 200 kilo Francs, including installation. This high cost of investment is exceeded by the operating and maintenance cost.

Technical progress and advanced technologies tend to lower these prices and therefore allows the use of online monitoring where it was not affordable a few years before. But some other aspects are also problematic, such as reliability and easiness of operation, they can be solved by user's feedback and manufacturing at a larger scale. It is always surprising to see that high cost of an analyser is often joined with lack of reliability and complexity. Training of the operators is one of the keys to success.

An other key is specification, a clear methodology must be followed before obtaining online measurements : Users needs definition, supplier consulting, choice based on financial and technical evaluation, well defined ordering, installation according to standard guidelines, commissioning, adequate maintenance and operation.

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