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Best Available Techniques as a sustainability tool in manufacturing: case study in the dairy sector

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Abstract

Best Available Techniques encompass preventive and end-of-pipe solutions aimed to contribute to the sustainability of the European industry. They are determined by the official Sevilla Process based on extensive data collection and analysis, supporting formal negotiation steps. This article presents a statistical multicriteria method applied to the dairy sector to help determine reference sites likely to use BATs. This 5-step methodology is based on two classifications: representative or performant sites. Performant sites selected by the Pareto front analysis are better than representative sites. In the representative analysis, the size of installations seems to be inversely proportional to their environmental impacts.

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Keywords: Best Available Technique; statistical analysis; reference installations; dairy sector

1. Introduction

Best Available Techniques (BAT) were first introduced in 1996 by the Integrated Pollution Prevention and Control Directive [1]. Their role was then extended and strengthened by the Industrial Emission Directive in 2010 [2]. Moreover, they have become an essential tool of the European regulation for regulating industrial emissions. The industrial sectors within the scope of the directive encompass about 50,000 installations (e.g. food, drink and milk; wood-based panels; large combustion plants; or sanitary landfills).

The overall goal of the IED is "to prevent, reduce and as far as possible eliminate pollution arising from industrial activities in compliance with the 'polluter pays' principle and the principle of pollution prevention" [2]. Furthermore, the concept of "Best Available Technique" is defined in the directive as "the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole" [2].

Thus, in the concept of BAT:

- **"Technique"** encompasses both "the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned" [2]. Therefore, it is not limited to a pollution abatement device but can also be a management approach such as an environmental management system.
- **"Available"** means the technique considered is "developed on a scale which allows an implementation in the industrial sector, under economically and technically viable conditions" [2]. These conditions take into consideration its costs and advantages, whether it is used or produced inside a given Member State or not, and if it is reasonably accessible to the operator.
- **"Best"** means that the technique considered is the "most effective for achieving a high general level of protection of the environment as a whole" [2].

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This concept has involved obligations at two levels. First, at European level, sector-specific reference document need to be drawn up. An official framework named the "Sevilla Process" has been established for information exchange on BATs. This process leads to the creation of Best Available Technique Reference documents (BREFs). It is thus based on a consensual step to gather the European "good-performing" industries. Because a large number of installations may be targeted, only a few reference installations can usually be studied and consequently need to be identified.

Secondly, at local level, operators have to compare environmental performances of a given installation with the information contained in their reference documents, in particular with BAT-Associated Environmental Performance Levels (BATAEPL). If they do not reach these BATAEPLs, they will have to provide a plan to improve their environmental performances or justify this impossibility with technical and economic arguments.

After a brief presentation of its context of application, this article describes a statistical method, applied to the dairy sector, for the determination of these sectoral reference installations. Then, the use of the concept of BAT as a sustainability tool in manufacturing, beyond its legal context of application is explored.

2. Context

2.1. Legal background

BATs are defined during an exchange information process named the Sevilla Process. This framework is described in an implementing decision [3,4]. Its first steps are aimed to define the environmental, economic and technical information about installations and techniques to be collected and shared among stakeholders. Fig. 1 illustrates the interactions among the various groups involved in this technical work in coordination with the European IPPC Bureau (EIPPCB). Thus, at European level, a Technical Working Group (TWG) composed of representatives of Member States, the European Commission, the Industry, and environmental NGOs is created. Its first task is to define the scope and the “key environmental issues” which will be considered. In order to coordinate the national contributions to the Sevilla Process, discussions among stakeholders are optionally undergone by a "shadow group". This shadow group can include representatives of the industry, national authorities and environmental non-governmental organisations, depending on the choices of the Member State.

After publication of a BREF, site operators and environmental authorities are concerned with the application of the BAT conclusions since they use the BREF in order to verify that an installation has a level of environmental performance comparable to BATs'.

Then, an extensive data collection is carried out, targeting performances and characteristics of sites currently operating in Europe. The transition from this step of information analysis to the definition of BATs highly relies on the expertise of its actors with a risk of biased assessment due to differences of interpretation.

The outcome of this process is a reference document (BREF) whose most important aspect is a description of sectoral BATs and emission levels associated with these techniques (BATAEL). The “BAT conclusions” extracted from these BREFs are published as European Commission Decisions and thus, bear a legal value which makes them essential to the directive.

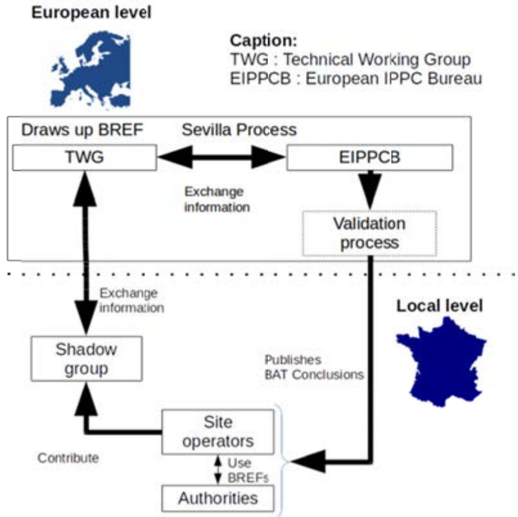

Fig. 1. Interactions among stakeholders involved in the IED.

Furthermore, other sectors, outside the scope of the IED must also apply BATs (e.g. nuclear installations in France [5]) whereas they do not possess any framework similar to the Sevilla Process.

2.2. Previous works on BAT selection

Several methods have been developed since the late 90s to help decision-makers to determine BATs at sector or installation levels [6–10]. They have been analyzed for this project in a previous literature review [11]. The main teachings of the study of existing researches was that they address three main issues: (1) local application of the IPPC directive or the IED for operational permits [9,10]; (2) selection of BATs at industrial sector scale with tools ranging from expert judgment [6] to Life Cycle Assessment [7] or potential impact assessment [8]; (3) determination of emission levels associated with BATs (BATAELs) [12]. In sectors outside the scope of the IED, like in the nuclear industry [2], operators must prove that they apply BATs but have no reference documents and therefore have to find their own references to assess their installations. They can do so using existing BREFs to find applicable techniques although they were not made for their sector or resort to their own resources to look for any helpful data.

Previous works on the topic of BAT identification differ according to their goals and scope. A local BAT determination method mainly relying on expert judgment was found [6,12], while two other methods were aimed to reduce subjective elements [13,14]. Thus, Geldermann and Rentz

[13] relied on more factual parameters to assess techniques, and the National Observatory of Athens [14] used mathematical approaches to guide the decision.

Moreover, the number of installations considered differed. When this number was too high to consider every single installation, a sampling was used like in the Sevilla Process [3,13,14].

The Sevilla Process and Dijkmans' method [6] focused on emissions, while also considering larger performance criteria. However, Geldermann and Rentz [13] targeted environmental impacts, and the National Observatory of Athens [14] on economical valuation of impacts.

Basically, all the existing methods were about on the selection of techniques and their associated performance levels without explaining the upstream decision process based on the selection of installations, except in Polders et al. [12]. The only reference for this preliminary step, which is essential to identify environmental performances associated with BATs, is the Sevilla Process [3,4].

3. Methodological approach applied to the dairy industry

In the framework of the IED, reference installations are used to define BATs and to determine associated environmental performance levels. The method, presented here in an application to the French dairy industry, is a statistical approach which considers several environmental indicators in a classification and selection process. Its outcome is a list of a small number of installations chosen according to their shared environmental characteristics or their low values of consumption and emissions. Economic and technical aspects are considered through expert judgment in a later phase which is not presented here.

3.1. General methodology

The developed method consists of five steps (Fig. 2). First, the scope and objectives of the study are defined. Three main items are required: the population to be studied, the variables considered in the statistical analysis, and the normalization used to consider the size of the installations.

Secondly, data previously collected are processed in order to correct possible errors and to ensure consistency of data types (numerical or textual). Missing data may dramatically influence the analysis; therefore an imputation method based on random forests [15] was used in order to mitigate this effect.

Thirdly, a statistical analysis is carried out to classify the installations. The language for statistical computing R [16] was used to identify groups of installations based on their consumption and emissions. Two approaches were used. The first one is a characterization of the consumption and emissions of the installations thanks to a Principal Component Analysis with hierarchical clustering [17] which enables to identify clusters of installations with similar characteristics (representative approach). The most representative installations are here defined as the closest to the center of their class. The second approach is aimed to look for optimal installations minimizing the variables considered (performant approach) thanks to the calculation of a Pareto Front in order to select the installations with the lowest values considering all the variables and therefore, the environment as a whole [18].

Fourthly, a few installations are selected, according to their proximity to the center of their class in the representative approach and their presence on the Pareto front or not for the performant approach.

Finally, performance levels of these selections for each variable are analyzed and compared to the population studied.

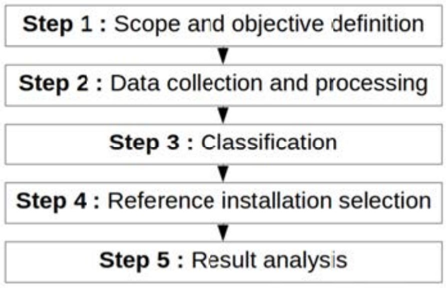

Fig. 2. Steps of the method.

3.2. Data used

The French dairy federation (CNIEL) provided data collected to prepare the revision of the "Food, Drink and Milk" (FDM) BREF. Thus, qualitative and quantitative information on installation characteristics, production, consumption and emission levels were made available for this study. They concerned a total of 115 IED installations located in France. The data collection was not comprehensive and some data were missing.

3.3. Application to the French dairy industry

3.3.1. Step 1: Scope and objective definition

The goal was to propose a list of reference installations for the French industry. Considering the choice of possible parameters, 16 scenarios could be carried out. The parameters chosen were the closest to the scope and key environmental issues defined during the kick-off meeting of the revision process for the Food, Drink and Milk (FDM) BREF [19].

Thus, nine variables, expressed as flows, were considered to classify the installations: energy consumption (EC), water consumption (WC), volume of waste water (WW), chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), total nitrogen (TN), ammonium nitrogen (AN) and total phosphorus (TP). Several variables were discarded due to a lack of data (Total Organic Carbon and chloride ion) or because of their specificity to a certain activity (dust emissions for installations manufacturing milk powder). In this example, emissions were expressed as specific loads (mass of pollutant released per mass of product manufactured or mass of raw material used [3]).

Finally, the size of installations was considered according to the input of processed milk and only 48 installations discharging directly their waste water into the environment were considered [19].

3.3.2. Step 2: Data collection and processing

The data collected by the French industry were verified and missing data were imputed to obtain a complete set of installations [15].

3.3.3. Step 3: Classification

Classifications were made according to both representative and performant approaches. Thus, 3 classes (groups) were found for the representative approach: class 1 contained 36 sites whose emissions and consumption are similar enough to form a cluster; class 2 was constituted of 11 sites whose energy consumption, water consumption and volume of waste water is larger than in the other class (Fig. 3). Besides, it had lower average levels of emission per ton of input of processed milk than class 1 except for total and ammonium nitrogen. Finally, class 3 contained only 1 site whose energy consumption was lower than the other two and emissions were much higher for each variable.

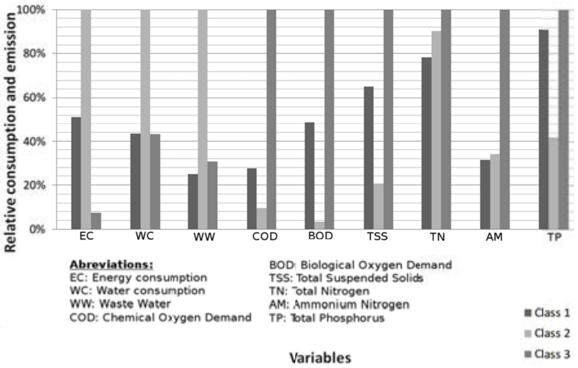

Fig. 3. Average consumption and emissions for the classes obtained with the representative classification for direct discharge sites.

Then, statistical hypothesis testing was done to look for other variables which might influence the classification. In this case, only the input of processed milk and the mass of manufactured products appeared as significant in the classification. The main product or other characteristics did not seem to influence the classification. Thus, class 1 contained the largest installations both in terms of input dairy matter and mass of products manufactured. Class 2 included the sites with the smallest productions and class 3 was a single site with lower than average input dairy matter for an intermediate production. In terms of consumption and emission levels, class 1 had lower values than class 2 for each variable whereas installations in class 2 were smaller than in class 1. Therefore, emission and consumption levels appeared to be inversely proportional to the size of the sites. It is to notice that this trend was similar in the other scenarios studied.

For the performant approach, the calculation of the Pareto front provided 6 installations whose consumption and emission levels were the lowest considering all the variables [18].

3.3.4. Step 4: Selection of reference installations

In the representative approach, installations were sorted according to their class and distance to their center. In this example the selection criterion was to obtain at most 15 installations. Thus, 3 sites in class 2 and 11 in class 1 were selected due to their closeness to the center of their respective class. The site in class 3 occupies the last spot but, considering its singular consumption and emission values, it may be a particular case whose selection would have to be approved by expert judgment or further investigations. In this example, it was considered separately from the others to prevent it from altering the comparison among average values in the following step.

With the performant approach, 6 optimal installations were identified and therefore kept. The number of installations obtained with this approach may vary according to the number of variables considered. Another set of variables may have provided a different outcome.

3.3.5. Step 5: Result analysis

This step aims at comparing the sites selected with the rest of the population in order to consider the "representativeness" of the selections. Thus, two analyses have been carried out. Since the relative levels of emission and consumption have been used in the classification, the first result considered here was a comparison of the values for the variables used in the statistical analysis (step 3). Thus, a comparison of the average consumption and emission levels showed that both selections were below the population average (Fig. 4). Emissions for the performant approach appeared to be lower than the representative selection except for COD and BOD. This seemingly odd result could be explained by the Pareto front approach. Indeed, it seeks for a compromise among variables; therefore the installations considered cannot have low levels on all the variables. A more detailed statistical analysis of these results has been carried out but is not showed in this article. It confirms that the methodological approaches lead to coherent results compared to the definition of representative and performant installations.

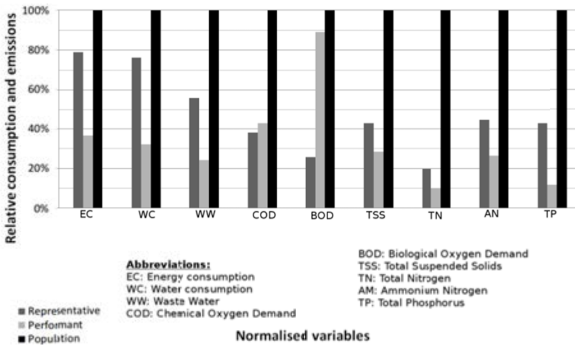

Fig. 4. Comparison of the average levels of consumption and emission of the selections and the population.

Since an important concern is the potential impact of the decisions made in the selection of reference installations, the percentages of sites from the whole population which have, for each variable, a larger value than the selection are given (Fig.5). In this simplified example, the comparison was made with the average value of the selected sites. Thus, the performant selection would be more stringent if used to determine emission limit values. Such a tool could be helpful at the level of shadow groups to foresee the possible impact of a given selection for the national industry. This can be viewed as an estimation of the number of installations which would need to adapt their emissions to potential emission limit values deduced from these selections (Fig. 5).

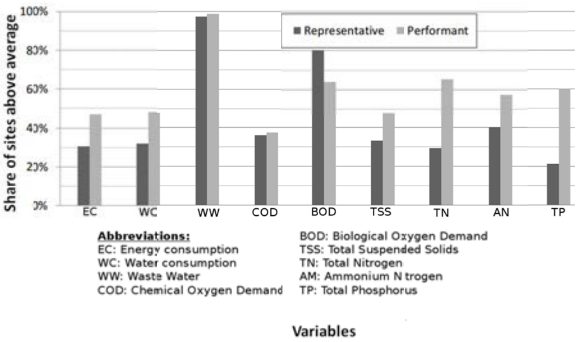

Fig.5. Share of sites which would have to make an effort to reach the average of the selections.

Thus, a larger share of the population had higher values in the performant selection compared to the representative approach. For the latter, 31 to 52 % of the total number of installations would have to adapt its emission levels, if deduced from this selection, whereas 53 to 92 % would be concerned with the performant approach, which would imply dramatic changes for the sector. This result is consistent with what is expected from a representative or performant selection of installations.

4. Discussion: BATs as a contributor to sustainability

The very definition of BAT already involves a relation with sustainability as defined in the Brundtland report [20] since it contains environmental, economic and technical considerations. Indeed, the environmental dimension is taken into account in the "high general level of protection of the environment as a whole" stated in the IED [2]. The economic aspects are included in the availability of a technique. Social considerations are included in the examination of chronic and accidental risks of industrial activities as stated in annex III of the IED [2] and a wider consideration of the impacts of BAT implementation for companies (in terms of employment, occupational safety, etc.) and for the society (e.g. impacts on health in the vicinity). Therefore, the concept of BAT contributes to the sustainability of the European industry.

Moreover, BATs, as defined under the IED, mainly focus on targeted substances and leave the assessment of their significance and impacts to other studies and expert judgment. Therefore a holistic approach could take place in the preliminary steps in order to use this statistical approach to highlight the most significant criteria. Indeed, although targeting key issues may ease the decision process, it implies a risk to miss important elements. In this aspect, a statistical approach may strengthen the decision to reduce the number of data.

Anyhow, balance between completeness and feasibility of such an analysis would have to be sought according to the objectives of the study. Moreover, social and economic aspects should be considered at the same level than the environment.

Since the BAT approach is a sectoral approach, it would be possible to assess the impact of technical alternatives on an entire industrial sector in a given geographical area by considering their availability or diffusion.

5. Conclusions

This article introduced a statistical multicriteria method to help to select reference installations in a view to identify Best Available Techniques. These reference installations can either be representative of a panel or the most performant among a studied population according to a multivariate approach considering their levels of environmental consumption and emission. This ongoing research is aimed to be applicable to industrial sectors under the IED and any other sectors concerned with BATs. Moreover, it is meant to be valuable for the existing decision processes carried out at any geographical levels, from local to international, providing that a sufficient collection of homogeneous data is provided. Developments on the method are still in progress for the determination of potential BATs from the reference installations.

Beyond the legal context of application of BATs, this statistical approach could probably be included in a sustainability tool to compare alternatives in a view to improve the sustainability of the industry by helping to identify key-issues to be investigated and improved according to the characteristics of an industrial sector. Moreover, with further research the proposed approach may be helpful to compare technical alternatives from a sustainable point of view.

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