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***"Gheorghe Asachi" Technical University of Iasi, Romania***


# INTEGRATED ENVIRONMENTAL AUTHORIZATION: ODOUR MONITORING THROUGH UNMANNED AERIAL VEHICLES

**Roberto Borghesi[1]*, Francesca Mauro[2]**

*[1]Institute for the Environmental Protection and Research (ISPRA), Rome, Italy*
*[2]Ministry of the Health, Rome, Italy*

## Abstract

To protect environment and public health, in the European Union industrial activity is subjected to Integrated Environmental Authorization (IEA), according to the provisions of the Directive 2010/75/UE. In Italy, the Legislative Decree n. 152/2006 regulates IEA procedure and states that ISPRA is responsible for the elaboration of a Monitoring and Control Plan (MCP) for large industrial plants, where odour impact assessment can be required.
Currently, odour monitoring is mainly carried out through dynamic olfactometry, which requires odour sampling. Such an activity can inevitably expose workers to occupational risks. So, to avoid/limit risks for workers involved in odour impact assessment, the authors investigated the scientific literature on Unmanned Aerial Vehicles (UAVs) through SciVal engine, recently recognized as a successful tool for different purposes. Hence, the paper's aim is evaluating the opportunity to use UAVs for odour monitoring and their influencing factors, as well as addressing further research in this field.

*Key words:* e-noses, IPPC, odour monitoring, UAVs

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## 1. Introduction

Even though industries are recognized to be a key component of economic well-being, there is scientific evidence that they can threat seriously both environment and public health (Patnaik, 2018). However, while industrial pollution can be considered a global phenomenon, different approaches have been developed to manage its issues in the world. For example, in the USA the Pollution Prevention Act (1990) demanded to EPA the establishment of a general source reduction program. In the European Union the Directive on Industrial Emissions (IED) stated a general framework further integrated with the Best Available Techniques (BAT) definition for each industrial sector (e.g. BAT Conclusions and BREF) (Vázquez et al., 2015).

According to the Integrated Pollution Prevention and Control (IPPC) framework (Directive 2010/75/EU), European operators must apply for an Integrated Environmental Authorization (IEA) to carry out industrial activities. The permit includes specific conditions for each installation, according to BAT Conclusions and national environmental laws or reference documents. Generally speaking, IEA is accounted to be valid for ten years. However, an ISO 14001 certificate or an environmental declaration according to EMAS Regulation can extend the deadline of the permit up to 12 or 16 years.

In Italy ISPRA elaborates a Monitoring and Control Plan (MCP) for installations of national concern (D.Lgs. 152/2006). A specific odour monitoring can be required in MCPs, according to the article 272-bis D.Lgs. 152/2006 and BAT Conclusions.

Such a request is due to evidence of many industrial activities (e.g. refineries, chemical plants, landfills etc.) causing odour emissions with nuisance

* Author to whom all correspondence should be addressed: E-mail: roberto.borghesi@isprambiente.it

and health disturbs (Guadalupe-Fernandez et al., 2021).

Just to illustrate this concept, it is sufficient to consider that in the (EU Decision 902/2016), concerning the BAT Conclusions on treatment and management systems for wastewaters and waste gas released by chemical industry, BAT 20 details the monitoring and control plan contents for odours (included in an Environmental Management System). This plan should contain:

- the identification of odour sources, the exposure assessment and the evaluation of the odour impact in a specific area and time range;
- the description of methods used to evaluate odour impact;
- preventive and protection measures to mitigate odour impact.

Actually, odour impact assessment is mainly carried out through dynamic olfactometry (EN 13725, 2004), which firstly requires odour sampling. However, as observed in some chemical plants, such an activity could expose workers involved in sampling operations to Occupational Health and Safety (OHS) risks, via inhalation or dermic contact with toxic substances.

Throughout the world, some research projects have been developed to test indirect methodologies, thus evaluating the opportunity to use technology for a continuous odour monitoring rather than the traditional approach included in EN 13725. Electronic noses could been accounted as a successful tool since 2010s, even though a few applications had been already known in the first years of the millennium (Cipriano and Capelli, 2019).

However, some researchers have tried to overcome the concept of terrestrial e-nose for odour monitoring by approaching to unmanned aerial vehicles recently (Allen et al., 2019). Just to illustrate this concept, in the U.S.A. a group of researchers are working to validate a palm-sized prototype of drone able to smell odours (the so-called "Smellicopter") (Anderson et al., 2021). In Spain, the prototype "Sniffdrone" has been developed to detect sources of odours in a wastewater treatment plant and it is going to be patented to assess odorous impact (Burgués et al., 2021).

Moreover, in Italy a civil protection network has been established since 2020 to promote the use of drones for environmental monitoring according to standard procedures. About 100 vehicles and 100 pilots are involved in this network and ISPRA is actually part of it (SNPA, 2020).

Hence, with the goal to improve the odour impact monitoring, scientific literature about Unmanned Aerial Vehicles (UAVs) was further investigated. More in details, this paper aims to provide a scientific and systematic review of the literature about UAVs for environmental monitoring to answer this question:

*"Can we use Unmanned Aerial Vehicles to assess and monitor odour impact in Integrated Environmental Authorizations?"*

The remainder of the article is organized as follows: in the next section, there is a description of materials and methods used to carry out the literature review; Section 3 shows the results of this research and discusses potential application of UAVs in environmental and odour monitoring; finally, section 4 concludes the paper and addresses further research work.

## 2. Materials and methods

Making a systematic review means to collect and analyse data from published scientific papers to answer a specific question, in a way that can be defined transparent and reproducible (Snyder, 2019). Generally, systematic reviews are carried out by searching for scientific articles indexed in Scopus, Web of Science, PubMed, etc., as they contain most of research products, whose value is recognized at an international level. In fact, publications indexed in one of these databases are subjected to a strict and double peer-review process.

However, Elsevier has recently released a new research engine called SciVal to help researchers in the evaluation of their scientific performances. As demonstrated by (Kolosok et al., 2021), such a tool can be used to make literature reviews too. In fact, the sources of data for SciVal are English-written outputs (peer-reviewed papers, conference proceedings, books, trade publications etc.) included both in Scopus and in ScienceDirect databases. Publications, authors and affiliation information available in SciVal are updated about every two weeks, while Scopus and ScienceDirect databases are updated monthly. In addition to this, SciVal is equipped with specific algorithms (related to automatic text mining methods), making easy the papers' selection, with reference to a specific research area (Elsevier, 2015).

Hence, considered the advantage of text mining algorithms included in SciVal, the systematic review about the use of UAVs/drones for odour monitoring was carried out according to the following procedure:

a) Pre-screening of the total database, concerning the definition of the Research Area in SciVal;
b) Screening of papers among those ones selected through the Research Area, according to specific selection criteria;
c) Publication Set Analysis, through abstract reading;
d) Full text analysis of papers, according to some quality criteria, partially derived from (Olsen et al., 2020) and stated in Table 1.

The definition of the "Research Area" was carried out according to the following steps:

1. Definition of the enter query string. This string should include some entering keywords, allowing text algorithms to calculate new related keywords.

For the stated purpose, the following enter query strings were considered:

a. "(UAV* OR drone*) AND (gas*OR odour*) AND (monitoring OR control)";
b. "(UAV* OR drone*) AND environment* AND (monitoring OR control)";

2. Evaluation of the papers' time range. As in Scopus, you can look for publications in a specific temporal period. This review was elaborated considering scientific papers published in the last five years (from 2016 to 2021);
3. Definition of key subject areas to make a first screening of information. In this case, Engineering, Environmental Science and Chemical Engineering were firstly selected;
4. Definition of organization types. In SciVal you can define the Research Area even through the category of the authors' organization (Academic, Government, Other etc.), as the main goal of this engine is to link researchers all around the world. However, as the main focus of this review was the content evaluation of research works, the authors' affiliation was not considered.

Once the research area was defined, the total amount of papers was further selected according to the following criteria:

5. Stage of the publication: only final articles were included;
6. Sub-subject areas: we selected only papers related to Environmental Science, as the main purpose of this review is related to environmental monitoring;
7. Type of publications: only articles and conference papers were considered.
8. Before evaluating full text of papers, a publication set analysis was carried out by reading abstracts.

In Fig. 1 the scheme of the entire procedure is provided.

## 3. Results and discussion

On the 11th of December 2021 the entry query string "(UAV* OR drone*) AND (gas*OR odour*) AND (monitoring OR control)" did not result in any kind of literature product, recognized by the above-mentioned databases (Scopus and Science Direct).

By contrast, on the same date, the SciVal engine produced results reported in Table 2, through the second input string "(UAV* OR drone*) AND environment* AND (monitoring OR control)".

**Table 1.** Quality criteria to assess full text papers

| ***Quality Criteria*** | ***Description*** |
|---|---|
| **Q1** | The study addresses odour or gas emissions characterization through unmanned aerial vehicles |
| **Q2** | The research objectives are clearly defined |
| **Q3** | The context of the study is explained and gives an overview of existing research on the topic |
| **Q4** | The paper discusses and identify possible limitations in the reported research. |
| **Q5** | The study can be considered externally valid |

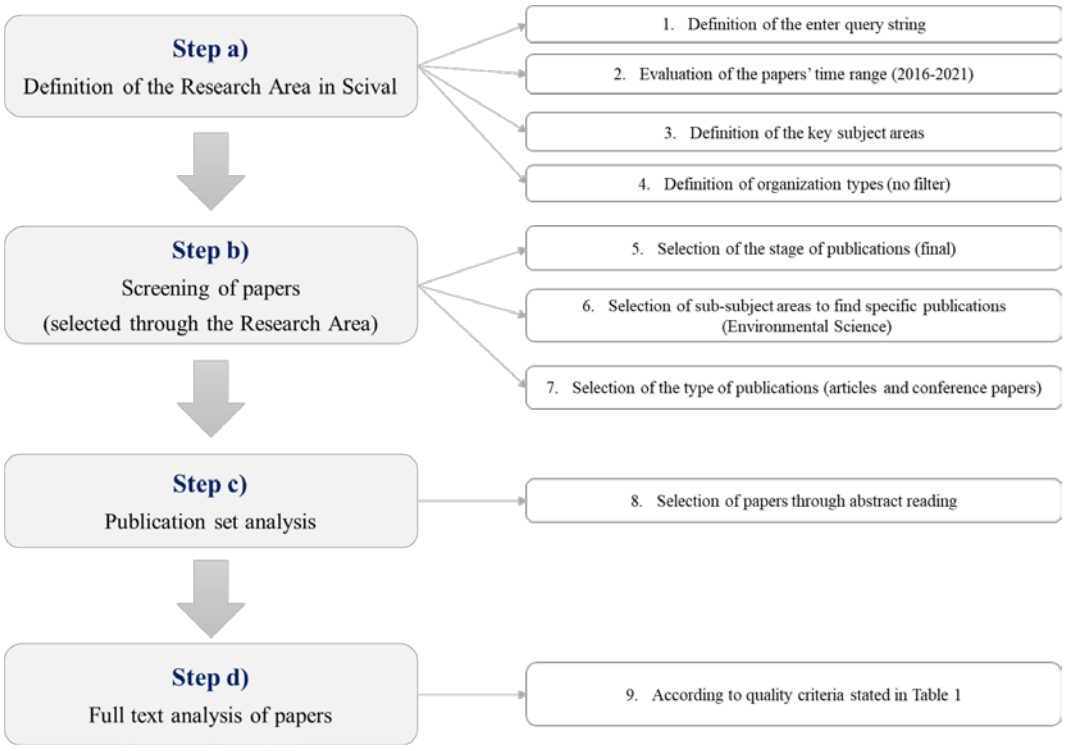


**Fig. 1**. The procedure developed to make the literature review

**Table 2.** Global results of the literature research

| ***Time range:*** *2016 – 2021*<br>***input keywords string:*** *"(UAV* OR drone*) AND environment* AND (monitoring OR control)"* | |
|---|---|
| ***Step of the procedure*** | ***Total number of papers*** |
| **Step a)**<br>Definition of the Research Area | Total matching publications (all subject areas): n. 5515<br>Matching publications with relevant subject areas for the stated purpose: n. 3661<br>1. Engineering: n. 3186 papers<br>2. Environmental Science: n. 542 papers<br>3. Chemical Engineering: n. 99 papers |
| **Step b)**<br>Screening of papers | Phase of Step b):<br>5. Selection of the stage of papers: final (n. 3594)<br>6. Selection of Article and Conference Papers: n. 3359<br>7. Selection of the sub-subject area: Environmental Science (n. 474) |
| **Step c)**<br>Publication Set Analysis (PSA) | • Papers rejected after PSA: n. 134<br>• Valid publications related to using UAVs for environmental monitoring: n. 340 |
| **Step d)**<br>Full text analysis (FTA) | • Papers submitted to FTA: n. 39<br>• Valid publications: n. 22 |

*3.1. Results of the Publication Set Analysis (PSA)*

*3.1. Results of the Publication Set Analysis (PSA)*

Before carrying out the Publication Set Analysis (PSA), the publication set was analysed with reference to key-phrases, elaborated by Scival engine from the input keywords string. Relevant key-phrases can be assessed directly in SciVal according to several variables (e.g. scholarly output, number of collaborations, citations etc.). In Table 3 an extract of such an analysis is reported with reference to scholarly outputs in the period 2016-2021. Then, the total amount of publications (n.474) extracted at the end of Step b) was selected through the Publication Set Analysis (PSA), which mainly consisted in abstract reading. The PSA was conducted through the means of:

- The SciVal engine, where abstract reading is directly available for each publication;
- Microsoft Excel tools, which allowed organizing the outcomes of Step b) in a table with the following columns: Title (Colum A), Authors (Colum B), Year of the publication (Colum C), Journal Title (Colum D), DOI (Colum E), Publication Type "Article/Conference Paper" (Colum F), Eligibility "YES/NO" for the Full Text Analysis (Colum G), UAVs application area (Colum H).

Hence, thanks to the PSA, the publication set was immediately divided in two categories: rejected papers and valid publications related to using UAVs for environmental monitoring.

In a second phase of the PSA, valid and rejected publications were identified for each year to evaluate, respectively, the cumulated distributions. Finally, all potential UAVs applications for environmental purposes were identified and papers were related to each one.

In the first phase of PSA, the main reasons to exclude papers were for example:

a) the paper only deals with technological issues of drones or UAVs, without highlighting information for specific environmental monitoring aspects;
b) The paper focuses the attention on the use of drones for security or safety issues;
c) The abstract does not allow the reader to distinguish key points of the publication;
d) The paper provides only a review of the state-of-the-art on UAVs, without any original application study;
e) The paper is focused on other topics, such as Geographic Information Systems, remote sensing platforms, elaboration models for remote sensing data etc., not related to specific applications of UAVs for environmental control.

In the second phase of PSA, cumulated distribution of publications related to environmental monitoring with unmanned aerial vehicles were elaborated with reference to the period 2016-2021. Such distributions were organized in histograms showing an increasing linear trend, both for valid papers (Fig. 2) and rejected ones (Fig. 3).

Then, every valid paper was related to a specific UAVs application area for environmental monitoring and global results were reported in Table 3.

**Table 3.** Top-three key phrases related to scholarly output

| **Scholarly output**<br>(results based on 474 publications) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Keyphrases** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **2016-2021** |
| **Unmanned aerial vehicles** | 20 | 30 | 48 | 73 | 79 | 88 | 338 |
| **Drone** | 12 | 24 | 18 | 41 | 46 | 54 | 195 |
| **Unmanned vehicles** | 15 | 15 | 29 | 36 | 38 | 38 | 169 |

### *3.2. Results of the Full Text Analysis (FTA)*

As mentioned above, none of the publications extracted with the second input keywords string allowed recognizing direct applications of UAVs for odour monitoring in the period 2016-2021. However, n.39 papers were submitted to the next Full Text Analysis (FTA), as related to applications of UAVs to air quality monitoring and, in a few cases, to industrial gas leaks control too. The first-mentioned research field was reasonably recognized the most related to odour monitoring. FTA was carried out in Scopus database by searching for those papers matching the quality criteria stated in Table 1.

During FTA, papers mainly related to particulate matter monitoring were excluded as not useful to answer to the question stated in the introduction. At the end of this phase, n. 22 publications were recognized as valid for discussion and distinguished in two categories: articles and conference papers. Moreover, reference publishers and journals were identified for such publication set. In Table 4 results of FTA are summarized.

### *3.3. Comprehensive discussion*

As stated in section 2, results detailed in section 3.1 have been achieved through the use of text mining algorithms, which are a distinctive feature of Scival engine.

The automatic elaboration of other keywords from the input string allowed creating a publication set in short time, by integrating two databases (Scopus and ScienceDirect). Such opportunity can be considered a great advantage when you are required to make a literature review: in fact, it avoids the phase of removing duplicates identified in two databases.

Results achieved from Publication Set Analysis were interpreted through an histogram (Fig. 2) showing how applications of unmanned aerial vehicles in detecting environmental changes have been undoubtfully going up recently. Such increasing trend has not been related to a unique research field, but to several subject areas as reported in Table 5. These results can be also confirmed looking at the top-three key phrases analysis reported in Table 3.

However, results achieved through PSA and FTA demonstrated that applications of drones in gaseous releases monitoring are actually less usual rather than those ones concerning forest and vegetation monitoring, waste and contamination control or land monitoring. So, it could be argued that:

- some application areas are more developed than others (*i.e.* forest & vegetation monitoring);
- using drones in industrial areas still remains a very challenging task.

**Table 4.** Bibliometric features of the full-text analysed papers (Legend: A = Article; CP = Conference Paper)

| **Full-text analysed papers** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2016** | | **2017** | | **2018** | | **2019** | | **2020** | | **2021** | | **2016-2021** | |
| **A** | **CP** | **A** | **CP** | **A** | **CP** | **A** | **CP** | **A** | **CP** | **A** | **CP** | **A** | **CP** |
| 1 | 0 | 5 | 1 | 2 | 0 | 2 | 0 | 6 | 3 | 2 | 0 | 18 | 4 |
| **Bibliometric features** | | | | | | | | | | | | | |
| **Publisher** | | | | | | **Type of papers** | | | | **Journal/Conference Proceedings** | | | |
| Elsevier | | | | | | A | | | | Atmospheric Environment | | | |
| | | | | | | | | | | Environmental Pollution | | | |
| | | | | | | | | | | Journal of Environmental Management | | | |
| | | | | | | | | | | Ocean Engineering | | | |
| | | | | | | | | | | Waste Management | | | |
| | | | | | | | | | | Journal of Environmental Sciences (China) | | | |
| Multidisciplinary Digital Publishing Institute (MDPI) | | | | | | A | | | | Atmosphere | | | |
| | | | | | | | | | | Chemosphere | | | |
| Springer | | | | | | A | | | | Arabian Journal of Geosciences | | | |
| Taylor & Francis | | | | | | A | | | | Journal of the Air and Waste Management Association | | | |
| Gh.Asachi Technical University of Iasi, Romania | | | | | | A | | | | Environmental Engineering and Management Journal | | | |
| Institute of Electrical and Electronics Engineers Inc. | | | | | | CP | | | | International Workshop on Metrology for AeroSpace, MetroAeroSpace 2020 - Proceedings | | | |
| | | | | | | | | | | International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe, EEEIC / I and CPS Europe 2020 | | | |
| | | | | | | | | | | OCEANS 2017 - Anchorage | | | |
| EDP Sciences | | | | | | CP | | | | E3S Web of Conferences | | | |

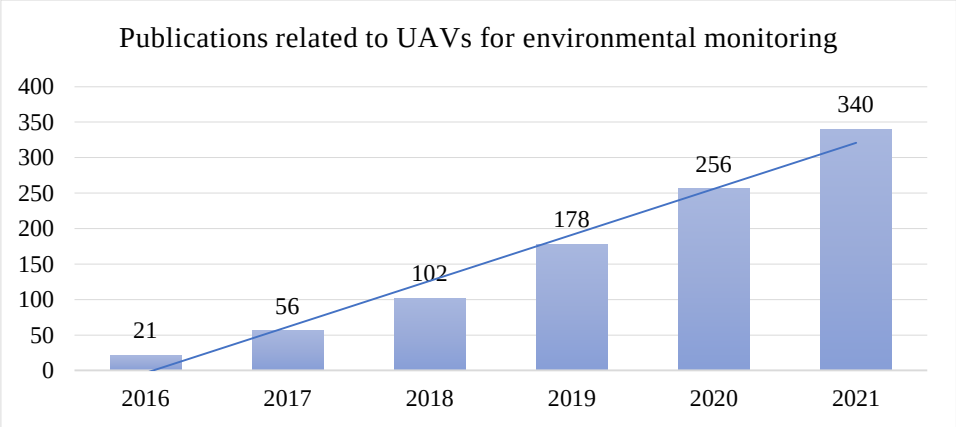


**Fig. 2.** Cumulated distribution of valid publications about using UAVs for environmental monitoring (2016-2021)

**Table 5.** Identified UAVs application areas through Publication Set Analysis

| ***UAVs application areas*** *(based on 340* papers)* | ***Short description*** | ***Number of publications*** *Time range: 2016 – 2021* |
|---|---|---|
| Forest and vegetation monitoring | This area concerns the application of UAVs to assess changes in forest and vegetation spectral conditions. Many applications have been related to marine vegetation too and required UAVs water-resistant. | 83 |
| Coastal surveying | This area concerns the application of UAVs to assess temporal changes in marine morpho-dynamics. | 38 |
| Air quality monitoring | This research area concerns the assessment of air pollution through unmanned aerial vehicles. Papers related to this field deal with particulate matter sampling, air pollutants dispersion etc. through drones equipped with e-noses. | 35 |
| Land and soil monitoring | This research field concerns the use of UAVs to evaluate soil health conditions as well as land use (residential, forest, for agriculture purposes etc.). Acquired imagery are further elaborated to assess variations in specific indexes, such as NDVI. | 33 |
| Waste and contamination monitoring | UAVs applications to assess shape and volume features of waste dumps and the extension of contaminated areas are here included. Many studies are currently about the use of drones to detect and characterize marine or beach littering. Other ones are related to the characterization of buried waste or illegal landfills. | 31 |
| Agriculture and farming practises | In this area papers regarding the use of drones to evaluate health conditions of cultivations or to assess farming practices are included. | 30 |
| Wildlife and animal control | Such research field includes papers addressing the use of drones to detect or control wild animals health conditions in large areas. Papers related to marine animals are available too. | 23 |
| Hydrology modelling | This research area concerns the use of drones for flood modelling, river sediment monitoring etc. | 22 |
| Quarries and dumps monitoring | Such area include articles addressing the use of drones for planning activities in dumps and quarries. | 10 |
| Urban environment monitoring | This area concerns the application of drones to civil infrastructures, such as highways, buildings etc. to assess their technical performances. | 9 |
| Cryosphere monitoring | This area includes articles about using UAVs to evaluate snow cover depth in glacial areas or to assess ice dynamics or dealing with typical factors of polar areas influencing the use of drones. | 9 |
| Radiation monitoring | This research area concerns the use of drones to analyze radiologic risk near nuclear reactors or areas contaminated by radioactive waste. | 7 |
| Industrial facilities control | This area mainly concerns the application of UAVs for leak detection and repair programs in industrial sites. | 5 |

*n. 5 papers were accounted to be across two or more identified application areas

To better understand how research on drones could evolve with reference to odour impact monitoring in industry, some influencing factors related to the use of drones for air quality or industrial gas leaks monitoring were derived from the 22 selected publications and organized in some categories. The following categories were established: Operations management, Manpower, Environment and Machinery. Some factors, not mentioned in the selected papers (i.e. those ones related to "Manpower"), were derived from ISPRA and environmental Italian Agencies professional

background about the use of drones. Then, all influencing factors on the use of drones for odour impact monitoring in industrial plants were organized through the means of an Ishikawa diagram. Published as a tool to assess quality in industrial processes, Ishikawa graph is now accounted to be one of the best logic instrument to evaluate cause-effect relationships. In fact, it shows a very flexible structure: for example, some applications of Ishikawa diagram have been reported to evaluate industrial sustainability (Mengistu and Panizzolo, 2021), waste management (Manojkumar and Rajayogan, 2021) or occupational health and safety (Górny, 2017). In Fig. 3 the final output of the above mentioned analysis is reported.

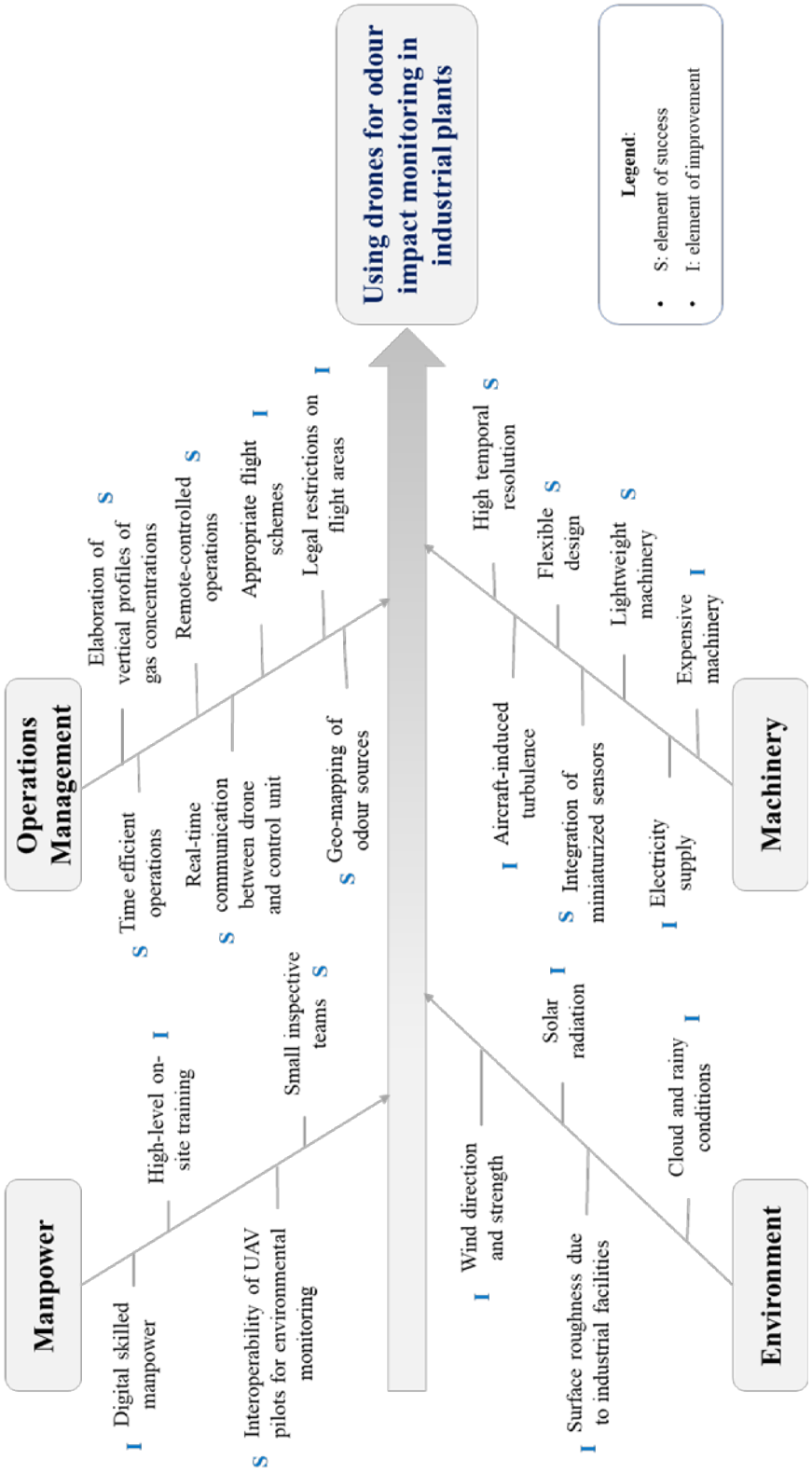


**Fig. 3.** Analysis of the influencing factors (Ishikawa graph)

Every factor was categorized as an element of success or improvement to better address the use of drones in such research field. Hence, the following results were achieved:

- the main successful factors are currently related to "Operations management" and "Machinery". Drones can be considered a flexible and lightweight tool, but also a valuable measure to prevent workers involved in odour impact monitoring from OHS risks, as they do not require the direct contact/exposure to the sources of odours;
- improvements mainly concern "Manpower" and "Environment" categories, such as the need for digital skilled manpower and models to better control data uncertainty due to meteorological parameters and turbulence phenomena.

### *3.4. Study limitations*

Even though this literature review pinpoints the recent state-of-the-art of drones for odour and environmental monitoring, some limitations were identified and are here discussed. Firstly, the review was highly dependent on the use of text mining algorithms to identify useful publications. Even though such tools allow selecting quickly a large amount of articles from two databases, they could lead to consider many off-topic papers with the increasing of literature production, as shown in Fig. 4.

Moreover, the study was aimed at defining current applications of drones with reference to the stated topic: so, publications were selected by considering only last five years. The choice of a short time period could be a limitation if you are interested in evaluating temporal changes in the specific subject.

Finally, another limitation is related to SciVal dependence on Scopus and ScienceDirect databases, powered by Elsevier. In this review, the largest amount of full-text analyzed papers were published by Elsevier. This result could be due to the automatic exclusion of papers indexed in other important databases (e.g. Web of Science, Google Scholar etc.).

## 4. Concluding remarks

A review of literature published in the last five years (from 2016 to 2021) on unmanned aerial vehicles for environmental monitoring was carried out to investigate the potential use of UAVs for odour impact monitoring in Integrated Environmental Authorizations, released to industrial plants according to Directive 2010/75/UE (in Italy, according to the Title III-bis of Legislative Decree n.152/2006). In fact, occupational health and safety issues for the operators involved in odour sampling were observed, addressing in this way the need to promote indirect methodologies to carry out odour impact monitoring.

Through the Scival engine, the study concludes that odour impact control through drones is still an open research field. In fact, in the period 2016-2021 no application were officially reported in SciVal engine with reference to such field, while only a few were accounted to monitor air quality and industrial gas leaks. Moreover, the authors discussed the initial question with an Ishikawa analysis of factors influencing the use of drones in odour monitoring to address further research in this field.

To sum up, with reference to IEA permits, this paper shows how environmental and health authorities may not agree on the use of UAVs for odour assessment, due to the lack of sufficient evidence. However, as demonstrated by current research projects throughout the world, the use of drones in odour monitoring could become a driver of innovation among researchers and professionals involved in such activities. For this reason, scientific experimental programs should be encouraged to better address the use of UAVs in the field of odour monitoring.

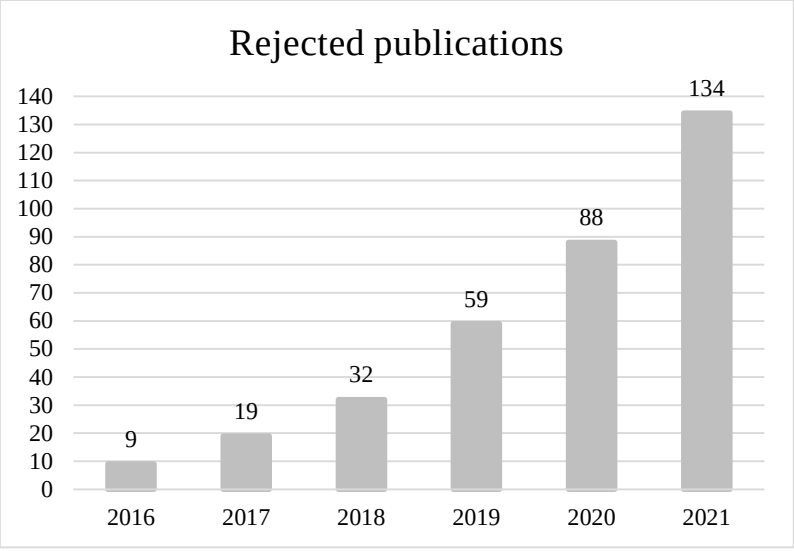


**Fig. 4.** Cumulated distribution of rejected publications through PSA (2016-2021)

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The authors declare no conflict of interest.

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