SENSING DISEASE WITH BREATH AND COMMERCIAL MOS SENSORS : A REVIEW

Justin D.M. Martin*, Muhammad Bailor Jalloh, Mauri Rosiers, Claudia Falzone, Anne-Claude Romain.

Sensing of Atmospheres and Monitoring (SAM), UR Spheres, University of Liège (ULiège), Arlon Campus Environnement, Arlon, Belgium

LIÈGE université — Arlon Campus Environnement

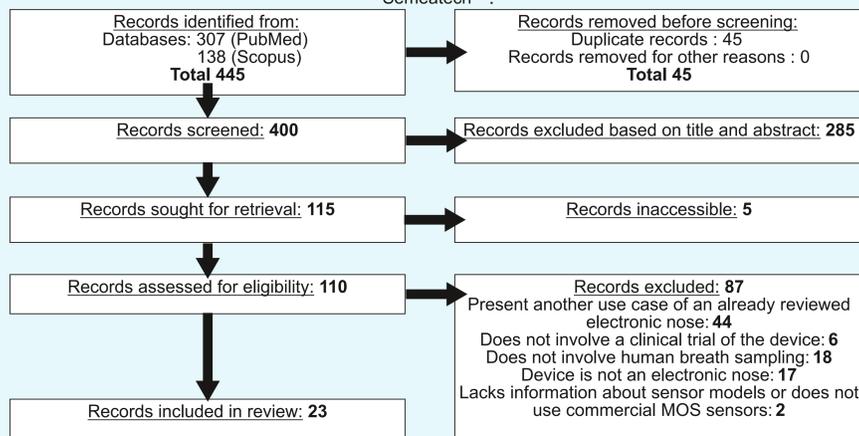**Sensing of Atmospheres and Monitoring**

OBJECTIVES

- In recent years, there have been many attempts at creating electronic noses to detect diseases using off-the-shelf Metal Oxide Semiconductor (MOS) sensors.
- This review aims at showing which sensors were used, which diseases were tried, and how well the clinical trials went.
- The goal is to give a view of what has been done and to help with future projects.

METHODS

- This review was made following PRISMA guidelines.

- Research was restricted to articles of 10 years of age or less. Reviews were excluded. Keywords included known commercial model names or commercial brands of MOS sensors, with the mandatory keyword "breath".

- The following brands were researched, along with their MOS sensor models :

Figaro Engineering™, SGX Sensortech™, Nissha™, AMS™, Sensirion™, IDT™/Renesas™, Bosch Sensortech™, Umwelt Sensor Technik™, Winsen™, FIS™, ScioSense™, OGAM™, Senseair™, MGK Sensor™, Semeatech™.

Records identified from: Databases: 307 (PubMed) 138 (Scopus) **Total 445**	Records removed before screening: Duplicate records : 45 Records removed for other reasons : 0 **Total 45**
Records screened: 400	Records excluded based on title and abstract: 285
Records sought for retrieval: 115	Records inaccessible: 5
Records assessed for eligibility: 110	Records excluded: 87 Present another use case of an already reviewed electronic nose: 44 Does not involve a clinical trial of the device: 6 Does not involve human breath sampling: 18 Device is not an electronic nose: 17 Lacks information about sensor models or does not use commercial MOS sensors: 2
Records included in review: 23	

REVIEW

- A total of 56 models of sensors from 11 manufacturers (in bold here above) are used in the reviewed papers.

- About a third (n=9) of the articles present several classification algorithms. Out of them, only the most performing according to the article was recorded.

Most selected classification algorithms in reviewed papers

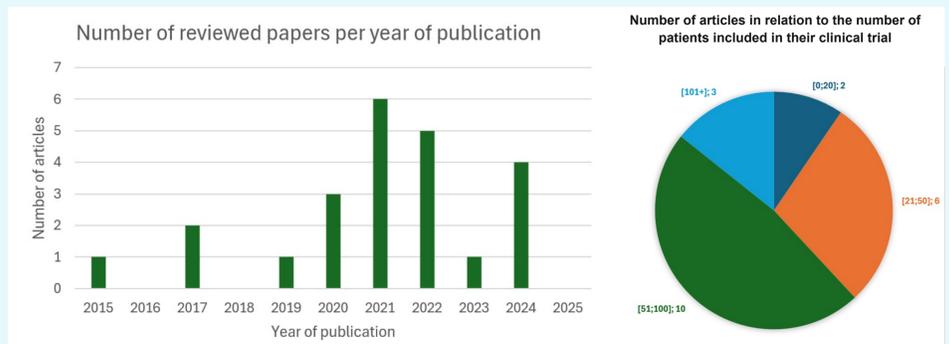| "Best" Algorithm	Occurrences	Median Accuracy	Median number of patients
SVM	7	92.0	80
LDA	4	93.1	62
Gradient Boost	2	90.1	168
Random Forest	2	88.6	33
Neural Network	2	89.1	44.5
Graph NN	1	97.5	70
Log. Reg.	1	71.0	10000
No algorithm	4		

- A single paper (n=1) combined both experimental sensors and commercial sensors.

- A few articles (n=3) used non-MOS sensors in the array for biomarker sensing along with MOS sensors. While some manufacturers' sensors are widely used (Figaro™, Winsen™), others are rarely included.

REVIEW

- While there is an increasing amount of articles and prototypes in the last years, the sample pools of clinical trials remains small for most articles, limiting the significance of the technological developments.

- A clear preference in sensor brands and target disease is showing.

Number of reviewed papers per year of publication

Number of articles in relation to the number of patients included in their clinical trial

Discriminated illnesses in reviewed papers

Most used commercial sensors in breath sensing e-noses

Rank	Sensor	Brand	Times
1	TGS 2620	Figaro	13
2	TGS 2600	Figaro	12
3	TGS 2602	Figaro	11
4	TGS 822	Figaro	9
5	TGS 2610	Figaro	8
6	TGS 2603	Figaro	7
7	MICS6814	SGX Sensortech	5
8	MQ-7	Winsen	5
9	TGS 8100	Figaro	5
10	TGS 2611	Figaro	5
11	TGS 826	Figaro	5
12	MQ-138	Winsen	4
13	MQ-135	Winsen	4
14	MQ-3	Winsen	4
15	TGS 4161	Figaro	4
16	BME680	Bosch	3
17	SGP30	Sensirion	3
18	CCS811	AMS-OSRAM	3
19	WSP2110	Winsen	3
20	MQ-8	Winsen	3

Most contributing commercial sensors in disease discrimination

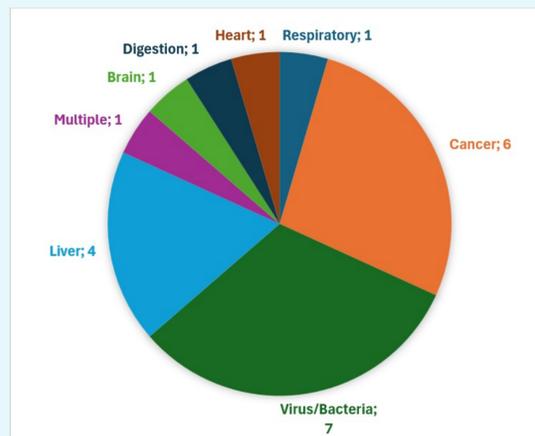| Rank	Sensor	Brand	Times	Diseases
1	TGS 2602	Figaro	5	Cirrhosis, Alzheimer, Parkinson, Lung Cancer, Heart diseases and more
2	TGS 2610	Figaro	3	Diabetes, Heart diseases and more
3	TGS 826	Figaro	3	Diabetes, Lung cancer and more
4	TGS 2620	Figaro	2	Diabetes, Lung cancer
5	TGS 2603	Figaro	2	Diabetes and more
6	MICS6814	SGX Sensortech	1	COVID19
7	MICS5135	SGX Sensortech	1	Alzheimer, Parkinson
8	MICS2610	SGX Sensortech	1	Alzheimer, Parkinson
9	QS01	FIS	1	Heart, lung, renal, kidney or breast diseases, diabetes
10	MP801	Winsen	1	Lung Cancer
11	TGS 8100	Figaro	1	COVID19
12	TGS 2600	Figaro	1	Lung Cancer
13	TGS 2444	Figaro	1	Cirrhosis
14	TGS 832	Figaro	1	Heart diseases
15	TGS 822	Figaro	1	Lung Cancer

CONCLUSIONS

- In this review, 23 articles about disease sensing electronic noses using commercial MOS sensors were selected (out of 445 identified records).

- This review could be extended by including articles using a same device in different contexts to better appreciate the gathered evidence. It was chosen not to include them for now to avoid bias (namely, the sensor choice dominence of prolific teams).

- There is growing interest in MOS-based breath sensing for disease detection, which leads research teams in using easily available commercial MOS sensors. A few sensor models (mainly Figaro and Winsen) dominate the field, mostly for Volatile Organic Compound detection. **Relatively few papers propose mixed technology arrays, preferring all MOS.**

- **Classification accuracies seem good but that may be an effect of the small sample pools.**

- **Many studies (65%) lack transparency** about which sensors and features are most important for disease discrimination. A systematic communication of these results could be beneficial to the field.

- **The creation of a database of sensor uses, defects and qualities from actual usage in experimental devices could help in creating better sensors and better electronic noses.** The systematic communication of the models of sensors used would also be an improvement. Finally, there is also a widespread lack of sample population in clinical trials for electronic noses, which therefore lack credibility as a screening or diagnostic tool.

MARTIN Justin D.M.
Post-Doc Researcher for S.A.M. laboratory, ULiège Arlon

CONTACT
- jdm.martin@uliege.be
- +32(0)63230947
- www.labo-sam.uliege.be

Litterature references are available : please scan this QR code

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