International Gas Union Research Conference 2011

THE GAS SMELL: A STUDY OF THE PUBLIC PERCEPTION OF GAS ODORANTS

Authors:

F. Cagnon

A. Louvat

V. Vasseur

GDF SUEZ – DRI-GRIGEN

France

ABSTRACT

In every country odorisation of distributed gases is required for safety reason. Although the formulation may vary the basis of the requirements are that the smell shall be perceived before a given concentration of gas in air, generally 20 % LEL, and that it shall be characteristic. The first requirement means that the odour intensity of the smell is sufficient. This can be evaluated through an olfactometric evaluation as proposed for instance in the Italian standard UNI 7133 or the French specification AFG 87-1. The last requirement means that the smell is not easily mistaken for a smell normally present in the ambiance. It is not easily verified as the smell perception, for untrained people, is based on the individual history but may also depend on some cultural or environmental factors.

Since the beginning of gas distribution odorisation has generally been done by adding reduced sulphur compounds to the gas such as sulphides (THT for instance) or mercaptans. These products smells are quite similar and are generally recognised as characteristic, leading to their identification with the "gas smell". Recently new odorants have been proposed in Europe based on acrylates compounds having a very different smell. Thus the question of the character of the smell, its perception and association with gas by the public is raised again.

GDF SUEZ investigated this question in a two steps study. With the collaboration of a French survey company, CSA, small focus groups were used to screen ten different smells. The ten smells were recognised as bad smells in order to avoid any hedonistic bias and included THT, TBM and acrylates. After a free discussion about the smells perception the focus groups were interviewed about the feelings that each smell generated. Finally they were invited to discuss about the gas smell, both in term of what it should be and about which smell would most closely fit with it.

At the end of this first step an identity card of what the gas smell should be was drawn and each of the ten smells that has been used were put on this map. Then five of these smells were selected, including THT and TBM as traditional odorants, an acrylate based odorant and two others as control smells.

These five smells were integrated in "scratch and sniff" cards that were used in interviews with individuals during a one week survey conducted by CSA. Four hundred persons were interviewed for each smell thus leading to a two thousand people panel. The interviews lasted about half an hour and covered many topics for different sponsor, with only five minutes for GDF SUEZ about odour. During these five minutes interviews the person had to give its spontaneous identification of the smell and then was asked several question in order to evaluate how its perception of the smell would fit the identity card of the gas smell. The word gas was introduced only at the end of the interview in a list of proposals about what the smell could be. Thus for each smell was obtained the spontaneous and assisted identification with gas or other products, but also how the smell would fit with the idea of a gas smell.

This communication is detailing the methodology that has been used in both focus groups and interviews. It will present how the gas smell "ID card" has been drawn and how the different smells are fitting that ID card. Then the analysis of the quantitative panel results will be detailed. The differences in perception will be presented taking into account the possible bias coming from age, sex, use of gas etc.

Acknowledgement: This study has been sponsored by the French companies GRTgaz and GrDF.

Table of contents

1. INTRODUCTION

Natural gas odorisation is a necessity for safety as it allows anyone with a sense of smell to perceive the odour of gas and thus be warned of its presence in the atmosphere. It is usually required by national regulations that distributed gases are odorised. This can be done by using different products and techniques *[1]*. In general the requirements ask that the smell is detectable before gas concentration in air reaches 20 % of the Lower Explosive Limit (LEL). Some regulations or technical guidelines may give precision about odour intensity or the normal sense of smell. Furthermore the gas industry can rely on methods and results to evaluate the odour intensity of gases or samples of gases (*[2], [3], [4]*).

Regulations may also introduce a requirement that the smell shall be characteristic. This is generally understood as a typical smell for gas or at least different from everyday odours in order not to be confused with them. Obviously this requirement is very difficult to validate. Natural gas has generally no odour as such and the typical smell of gas has for decades been given by the addition of sulphur compounds such as sulfides, Tetrahydrothiophene (THT) being the most common, or mercaptans, TertioButylMercaptan (TBM) being the most common for natural gas odorisation.

These sulphur compounds, although they have a slightly different odour, are generally considered as giving similar and distinct from usual smells. Thus if those products are used as odorants, the resulting smell of the gas is deemed characteristic, in the absence of odour fading resulting from the presence of contaminants in the gas or interaction with pipeline walls.

In the last years a new product has been qualified in Germany as a gas odorant, the GASODOR S-Free®. This product is a mixture of ethyl and methyl acrylates with traces of methylethylpyrazine *[5]*. Although its smell is clearly dissimilar to that of current sulphur products used as gas odorant, it was deemed acceptable for such use as it was evaluated as an alert smell *[6]*. This evaluation was done by a sample of 113 people that was submitted to six different smell, three of them being respectively THT, TBM and S-Free® and the others being jasmine, fish and roast meat. The interpretation of the results showed that THT and TBM were close together on one side, jasmine and roast meat on the other side with fish and S-Free® in intermediate positions, S-Free® being the closer to traditional sulphured odorants. This repartition is close to a hedonistic evaluation as jasmine and roast meat were defined as good smell, whereas THT and TBM are generally qualified as unpleasant.

As other acrylate based odorants are being proposed by manufacturers, GDF SUEZ decided to organise an evaluation of the perception of the gas smell as given by traditional odorants and S-Free®. The test was conducted in 2009 in two phases, one qualitative with about 40 people and the other quantitative with 2000 people with the collaboration of a French marketing and opinion research company CSA. The objective of the first phase was to screen a number of smells that could be used as reference to compare with the three odorants and to identify descriptors for the quantitative phase. Then the second phase aimed at evaluating the perception of five different odours, including the three odorants. This paper will detail the organisation of each phase and the results that were obtained.

2. QUALITATIVE PHASE

2.1. METHODOLOGY

2.1.1. Odours used

Ten smells were selected for the qualitative phase. Every smell was bad, ranging from mildly to highly offensive to avoid any hedonistic bias. They were presented in small vials filled with paraffin impregnated by the odoriferous solution or molecule in the case of THT and TBM. Thus all vials were identical save a label coded with a number and contained a white solid to avoid spillage. The vials were prepared by the French company EURACLI who also prepared the scratch and sniff cards used in the quantitative phase. Three contained THT, TBM and S-Free®, all three products being supplied by their manufacturers. The formulas of the other odours were not known, they were available at EURACLI laboratories as they had been used for some other operation.

They were identified as:

- Rotten egg,
- Gasoline,
- Skunk,
- Goat urine,
- Horse dung,
- Old shoes,
- Tar,

All odours were strong, and the participants were free to sniff the vials at varying distances in order to adjust the perceived odour intensity.

2.1.2.Focus groups

The qualitative phase was conducted with 10 focus groups each numbering four people, two men and two women. In five groups the participants were between 25 and 50 years old, in the five other groups between 51 and 70. Each session took place in CSA's Paris offices in a large room where the focus group was invited to sit around a table. One CSA's employee was moderating the session, one other taking notes. All participants were living in Paris or around but their personal profiles were mixed according to social criteria, housing type, etc. Each session lasted for about two hours during which four odours were studied out of the ten that have been chosen. Each focus group had one of the three gas odorant within the four odours studied.

2.1.3.Organisation of one session

The focus groups were organised as brain storming sessions to find out the evocations related to each odour. After a brief introduction about the rules of the session (no food, smoke or drink other than water, etc), an exercise about the different rooms of the house and an evocation of good and bad smells was conducted in order to warm up the participants. Then the four odours were studied successively in 20 minutes sessions. Each session followed the same protocol:

- Sniff of the odour followed by five minutes during which the participant had to write its spontaneous evocations coming from the smell.
- Then the group started discussing to present their spontaneous feelings, then the moderator proposed associations with images or words for the participant to agree or reject. Exercises were suggested to reproduce the formula of the smell or the emotions (fear, pleasure, anger, ...) associated with the smell.
- Then a second sniff of the vial was taken and the moderator asked the participant to dream from the smell. This exercise allowed the participants to summarise the session.
- Then a 3 minutes break was allowed.

After the four sessions, the participants were invited to sniff again all four smells and had to answer a questionnaire in which they had to:

- Give a key word for each smell.
- Rank all smells from the least to the most alerting and from the least to the most inconspicuous.
- Indicate which smell was the more "hinting of a danger", "Frightening", "adapted to natural gas".

This was the first direct indication of natural gas although gas, gas smell and such words had generally been spontaneously stated before during the sessions. Then the moderator launched a general discussion around the smell of natural gas, the participants being invited to explain their choice for the smell they associated to natural gas and to describe what qualities they would expect for the smell of gas.

2.2. RESULTS

2.2.1. Interpretation of results

The analysis first focused on the vision the participants had of the gas smell. The descriptions where synthesised to achieve an ID card of the gas smell and two criteria were identified that relates the adequacy of a smell with the gas smell.

Then the evocations of the ten odours were analysed in view of this ID card and a lexicon of descriptors that do and don't apply to the gas smell was built in order to prepare the questionnaires for the quantitative phase. Finally all odours were placed on a map summarising their position as regards the two criteria.

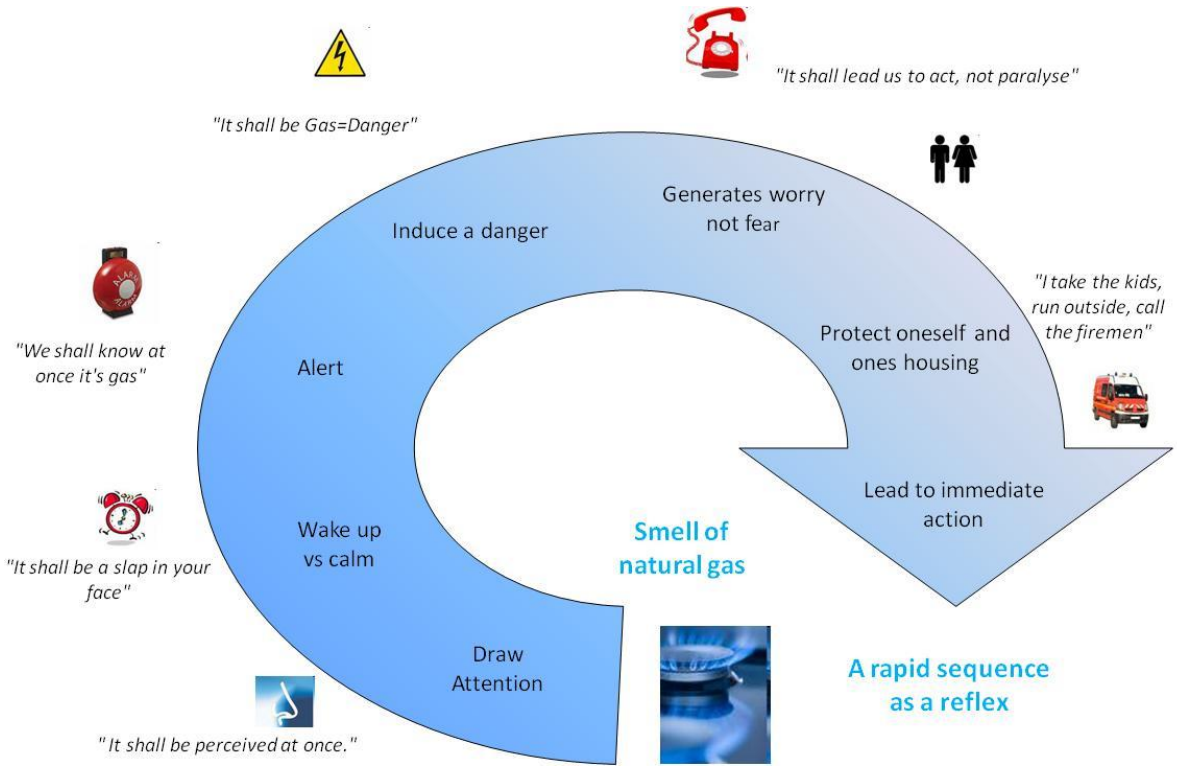
2.2.2. Natural gas smell ID card

The first result from this qualitative phase was an ID card. For the participants of this focus group the gas smell shall be:

- **Unique,** so that one can't confused it with other smell,
- **Persistent**, so that it won't disappear in a moment,
- **Encompassing**, so that the people will be oppressed and have to react,
- **Disagreeable but not incapacitating**, so that one can still act on it,
- **Aggressive**, so that people will be alert with a feeling of danger,

Its perception shall lead to action but no panic. This is summarised in Figure 1.

Figure 1: Natural gas smell ID card.



From this ID card, two criteria have been identified for a good "gas" odour:

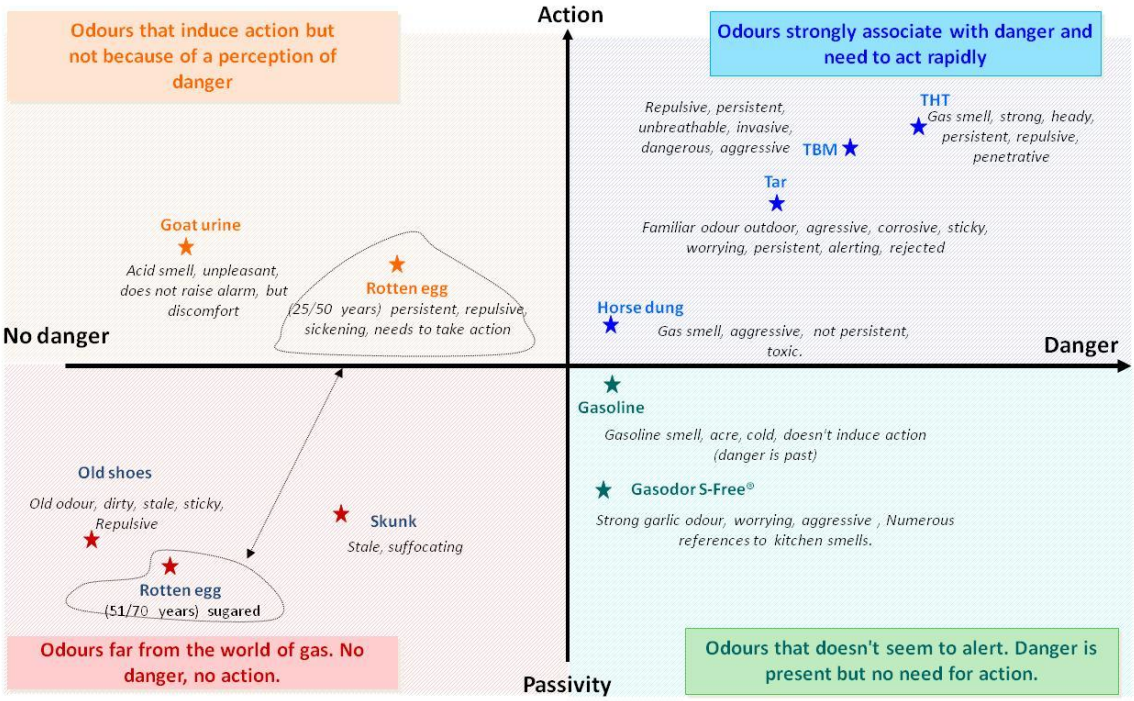
- It shall induce a danger
- It shall prompt action.

Thus the ten different odours have been positioned on a graph built against these two axes as presented in Figure 2. THT and TBM are in the best position as for the "would be" gas smell as being the smells raising more danger and need for action. On the opposite sits old shoes and rotten egg as

perceived by the oldest focus groups. Rotten egg is quite peculiar as there is a dichotomy in its perception between old and young focus groups, the younger ones being more prone to action when smelling this product.

As for the S-Free® odour it led to a surprisingly high number of references to the kitchen smells as garlic, onions, leek, etc. Goat urine induces a lot of action responses as being very disagreeable but no real sense of danger.

Figure 2: Relative position of the ten odours in the danger vs. action domain.



Thus the quantitative phase included THT and TBM as traditional gas odorants, S-Free® as the alternative. For the control smell, tar was chosen as it seems close to the traditional odorants and goat urine as a smell with a very different perception from all the others.

3. QUANTITATIVE PHASE

3.1. METHODOLOGY

3.1.1. General

The quantitative phase was conducted in all regions of France through face to face interviews at the home of the people surveyed by CSA's investigators during the course of an all purpose survey. The investigators were equipped with "scratch and sniff" cards prepared by the French company EURACLI specialised in microencapsulation. During the course of the all purpose survey, several themes were discussed for different customers (for instance food preferences, TV shows,...) and one set of questions were relevant for GDF SUEZ's enquiry. This sequence about odours lasted about 6 minutes out of the half an hour of the general survey and was placed at random within all the sequences. Each person interviewed was presented with only one card supporting one of the 5 odours that were selected for the quantitative phase. The cards have been prepared in order that they can generate a moderate to strong smell. People were free to adjust their perception by moving the card closer to their nose.

For each odour 400 persons were interviewed, leading to a total of 2 000 interviewed in all regions of France. Each 400 people sample was built according to the quotas methodology by taking

into account sex, age, profession, region and population of the place the interviewed is living. Although this was not taken into account in the constitution of the samples, the fact that the interviewed was using gas at home was checked at the end of the interview. For each odour, about 42 % of the interviewed were using natural gas, 33% LPG in cylinders and 25% were not using gas.

3.1.2.The interviews

The interviews were divided in three blocks. First the interviewed was asked to scratch and sniff the card given by the investigator and to express spontaneously what the odour was. They were asked to give their first and second guess if any but also to state on a 1 to 10 scale the degree of certainty about their recognition of the odour.

Then a list of propositions was presented for which people had to express their agreement in a four degree scale (Yes certainly, probably yes, probably no, certainly no). The first two proposals were to know if the odour was easily recognisable, and if it was pleasant. Then followed a list of nine proposals about what the perception of such smell would prompt. Four of them would be positive actions would the smell be gas ("Open the windows", "Call the emergency services", ...), three of them negative ("Don't do anything", "Spray deodorant",...) and two were relative of the perception of danger for health or explosion. Then the interviewed had to state on a 1 to 10 scale how dangerous he was thinking the odour was.

The third block of the interview was an assisted recognition of the odour. Seven propositions were made (Gasoline, Paint, Burned, Rotten egg, Gas, Garlic and Tar) and the interviewed had to state how close from the proposal was the smell using the same four degree scale as before.

The last question was about the use of gas for cooking, and if so, from network gas or cylinders. Then another sequence would start about a different topic, for a different customer's than GDF SUEZ.

Thus the sequence about smell was only making reference to gas in the last question and in one proposal of the last block of question. No other mention of gas was made during this sequence or the whole interview.

3.2. RESULTS

3.2.1.Data treatment

The data were interpreted to evaluate three aspects of each odour:

- Its recognition as gas smell, the possibility that it could be recognised as something else and its ability to draw attention.
- The degree and nature of danger it was evoking
- The way people would react to the odour.

For the questions asking an evaluation on a 1 to 10 scale the arithmetic average was built for each answer. For the questions where an adhesion to a proposal on a four degree scale was asked a synthetic indicator was built as follows:

- A *weight* from 100 (yes certainly) to 0 (Certainly not) with 66 and 33 as intermediate was attributed to each degree.
- The percentage of answers ($\%A_i$) for each degree was weighted and summed up to calculate the synthetic indicator.

Thus $SI = \sum_1^4 (Weight \times \%Ai)$. Thus SI can rate from 0 to 100, a value above 50 would mean that people are agreeing with the proposal, the more agreement the higher the value. Below 50 means a rejection of the proposal the more rejection the lower the value.

As natural gas is odorised in France with THT, a special attention has been given to potential bias in the identification of the smell of gas. This was done by looking for higher or lower than average association of a smell with the *gas smell* in one sub segment when compared with others. Segments were built per region (4), size of city (5 segments, Paris being one segment), sex, age (5 groups).... The distinction between gas users and non gas users was also made. Although some age group,

region and city size segments did respond differently than average to one or the other smell, no pattern was identified. In some cases THT was better associated with the smell of gas in other it was TBM, but no rationale could be found to explain that. The important information was that no difference was apparent between those using gas and those not using gas when associating one of the smell with the *gas smell*.

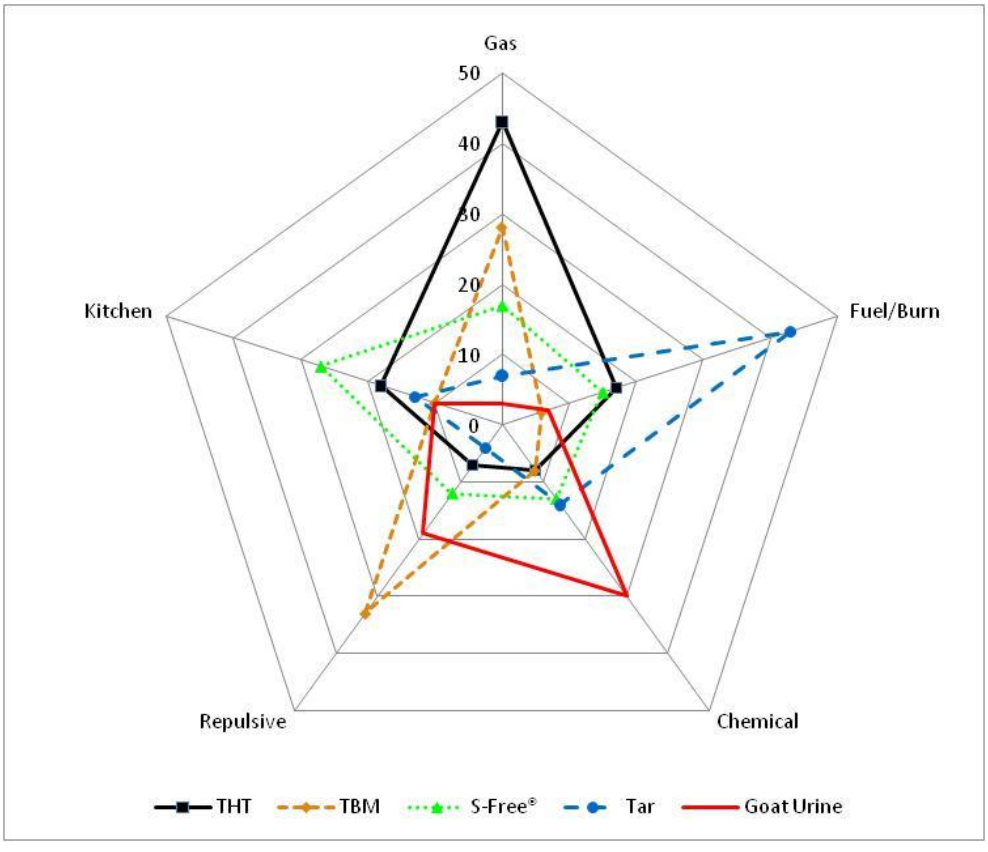
3.2.2.Spontaneous identification

Descriptors used for the spontaneous identification of the odours were closely related to that used during the qualitative work with the focus groups. They were gathered into five categories:

- Gas,
- Fuel or burned materials,
- Chemicals as cleaning materials, antiseptic (hospital smell), ammonia, etc.
- Kitchen smells such as garlic, onions, leek, shallots,...
- Repulsive, for descriptors around rotten material, including rotten egg, sewage, excrement,...

For each odour about 11 to 17% of the people were unable to formulate any guess. Figure 3 present the percentage of first answers in each category associated with the different odours. For all the odours, and whatever the answer was, people were quite sure that they had made a correct identification of the smell which was confirmed by the fact that the synthetic indicators for the question "Is this odour very characteristic?" were above around 60, with higher values for THT and TBM (70 and 69). Consequently second guesses were not numerous and were often giving descriptors close to that of the first guesses.

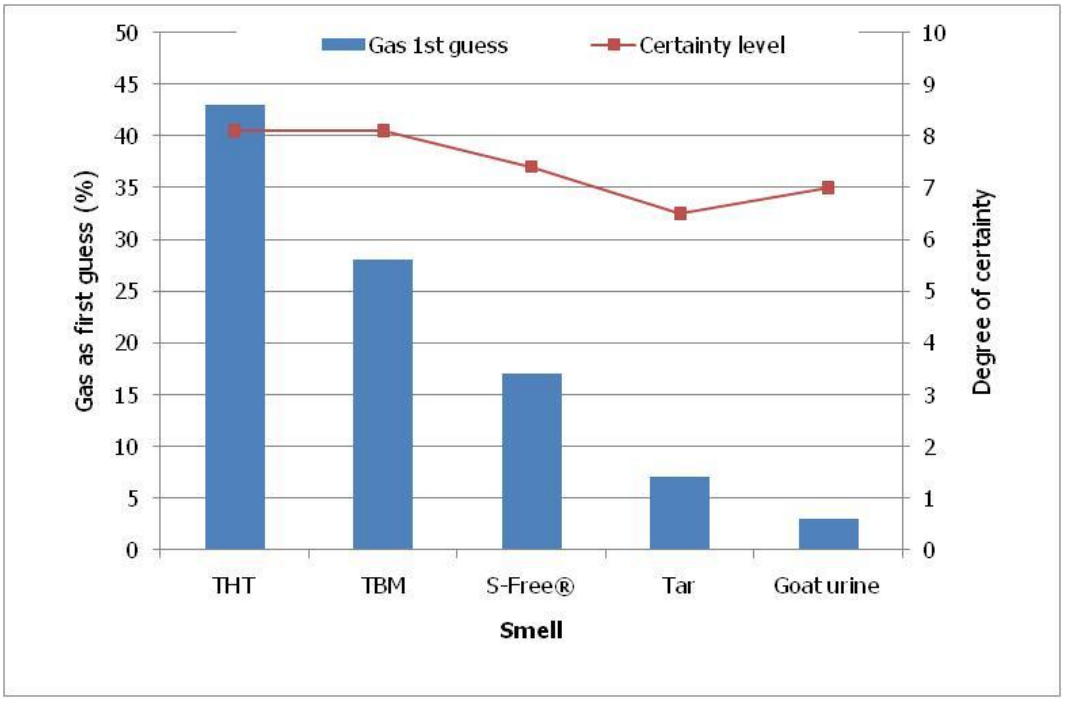
Figure 3: Spontaneous identification of the smell (1st guess)



Except for TBM for which a bimodal pattern applies (gas and repulsive for 30%) all other odours have one main axis. THT is spontaneously associated with gas and tar with fuel/burned material by about 43 % of the sample. Goat urine is mainly associated with chemicals and S-Free®

with kitchen smells but to a lesser extend as it concerns around 30 % of the sample. For people associating one of the odours with gas there is a high certainty level as shown in Figure 4.

Figure 4: Spontaneous identification of the smell as Gas.



Gas was quoted as a second guess by 6 % of the sample for THT and TBM, 4 % for S-Free®, 2 % for tar and 1% for goat urine.

The synthetic indicators of the answers about the pleasantness of the odours were low from 4 for TBM to 18/19 for goat urine and tar. THT and S-Free® ranked 10 and 11. Thus it can be considered that all odours were unpleasant and no hedonistic bias should be observed.

3.2.3.Perception of danger and action

The appreciation of the danger associated with the odour was very dependent upon its original identification as shown in Table 1.

Table 1: Level of danger for the odours (1 to 10)

Odour	All	Gas as first guess	Other guesses
THT	7.3	8.7	5.9
TBM	6.4	8.5	5.2
S-Free®	5.3	7.9	4.6
Tar	5.3	8.0	5.1
Goat urine	4.5	6.9	4.3
Average	5.76	8.02	5.48

In general THT was the odour recognised as the more dangerous, goat urine being the least dangerous. However, the sense of danger is much higher, whatever the odour, when it is associated with gas as first guess than when it is not spontaneously identified as gas.

This dichotomy is also seen when analysing what type of action is prompted by the odour. The answers of the seven questions about "What would you do if you smell this odour?" have been interpreted by:

- Adding their synthetic indicators for the actions that would be advisable in case of a gas smell (Open the windows/Call the emergency services/Exit the premises/Try to find the origin).

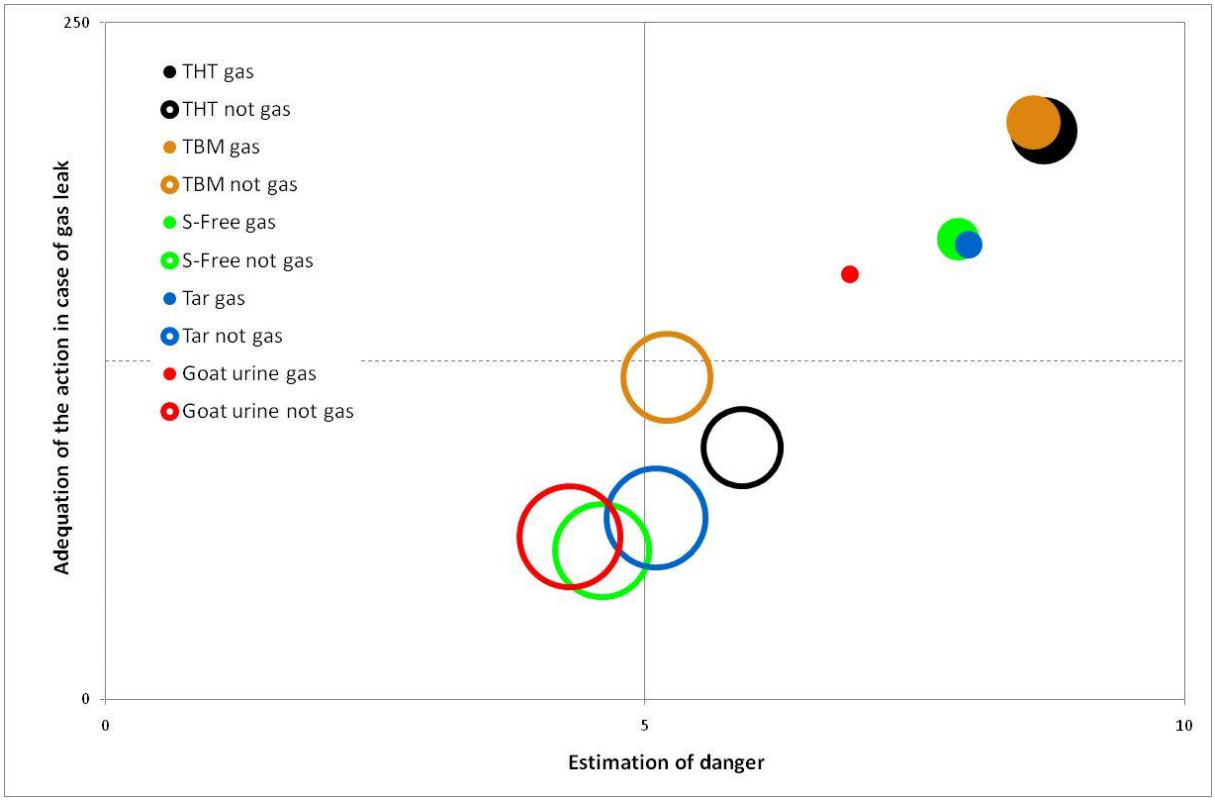
- Subtracting them for the ones that would be detrimental (Don't do anything/Spray deodorant/Wait and see).

Thus the higher the resulting figure is, the more adequate the actions would have been if the odour was the indication of a gas leak. Figure 5 is drawn to place the different odour in a similar representation as that of Figure 2. The filled circles correspond to the answers of those having spontaneously identified the odour as gas at their first guess. The empty circles correspond to those that haven't spontaneously recognised the smell as that of gas. The size of the circles represents the percentage of the sample in each case.

The answers are clearly distributed in two groups. If the smell has been identified as gas, then the people are feeling that is dangerous and will take action more adapted than when the odour is not identified as gas. For people associating THT or TBM with gas, both odours are giving similar results with the highest level of danger and adequate response to their perception. If S-Free® is associated with gas, the feeling of danger and the adequacy of the actions is slightly less. As for the other smells the number of people having associated goat urine or tar with gas is very small so the information is not very relevant.

When the odours are not associated with gas, the level of danger with THT is slightly higher than that of the other odours. TBM and THT are inducing more adequate actions with the three other odours being in a similar position. Clearly S-Free® is giving a similar response than the other bad smells.

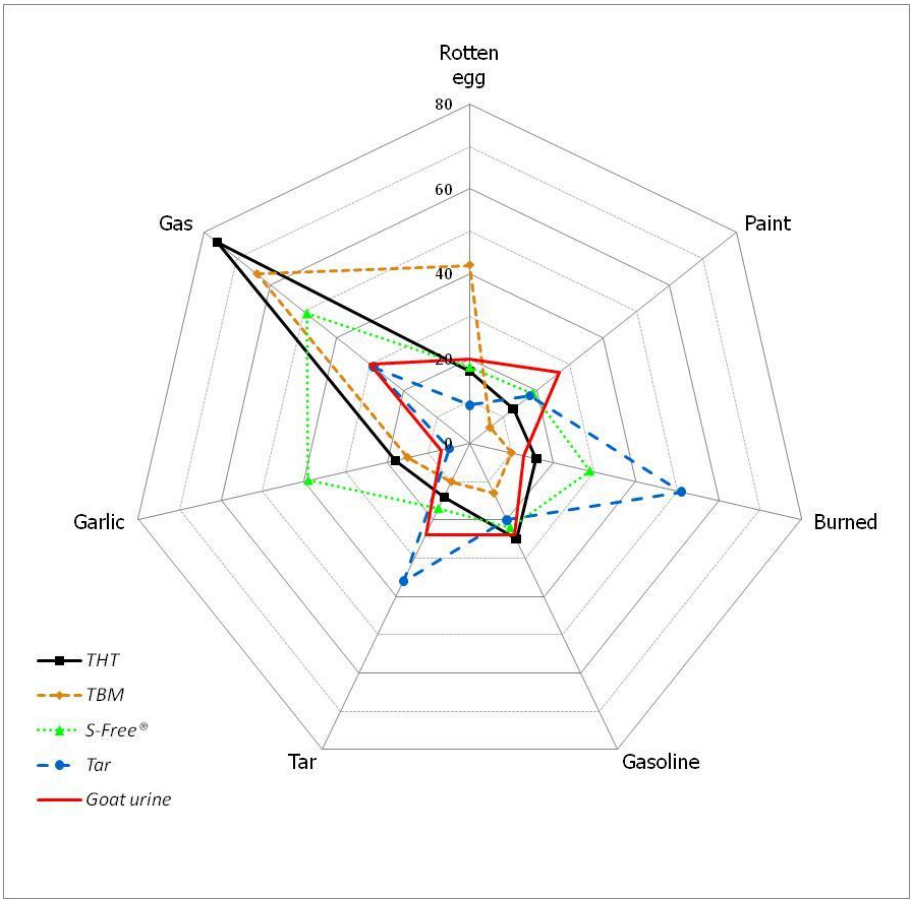
Figure 5: Position of the odours in a danger vs. action domain.



3.2.4.Assisted identification

The assisted identification results are presented by plotting for each odour the synthetic indicator reflecting the degree of agreement adhesion with the smell proposed.

Figure 6: Assisted identification of the odours

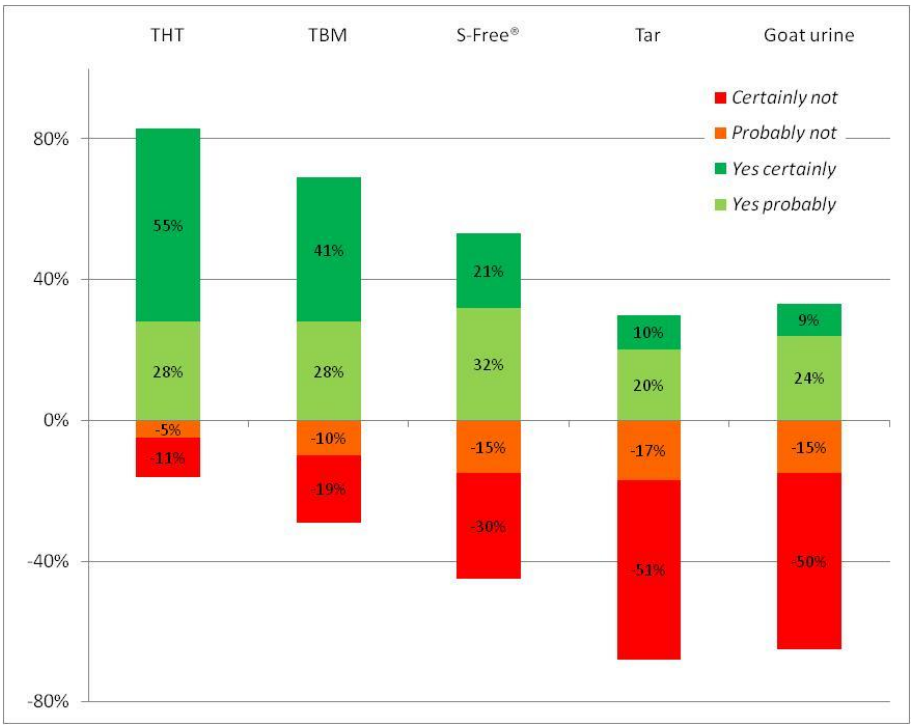


THT is strongly associated with gas and nothing else. For TBM a strong association with gas exists but the possibility of rotten egg is not totally rejected (SI ≈ 45). For S-Free®, people are loosely associated the smell with gas (SI ≈ 50) but not strongly rejecting the possibility of garlic. Tar is not very much associated with tar and more with burned material. As for goat urine, no positive association has been made.

A focus on the answers for gas is given in Figure 7. The positive values correspond to yes probably and yes certainly. The yes responses for THT or TBM are significantly higher than that for S-Free® in turn significantly higher than that of tar of goat urine.

Furthermore, only 16% for THT and 29 % for TBM are rejecting the association of these odour with gas whereas 45 % are rejecting the association of S-Free® with gas, to be compared with the 53% that are accepting it. Goat urine and tar are much more rejected as gas smell. A comparison of the answers to this question for people using gas for cooking and the others has shown no significant difference for the two populations.

Figure 7: Assisted association of the odours with gas.



4. CONCLUSIONS

The **spontaneous association** of THT with gas is high but still is not an evidence for a majority of the people. Although TBM is also readily associated with gas it may be identified with other products with a repulsive smell. S-Free® even if it is more associated with gas than the control smells is also leading to association with several other odours a number of them being in the kitchen universe.

The **assisted association** of THT with gas is very high and a majority of the people are sure of this. A significantly lower majority of people are associating TBM with gas and one person out of three is rejecting this association. This is probably related to the bimodal response to TBM, a fair number of people relating this smell with rotten egg. S-Free® is raising ambivalent answers. Although a short majority agrees that it is or could be gas, 30 % of the people are sure that it can't be.

The **perception of danger and actions elicited** by the perception of the different odours are clearly defined by the identification of the smell to gas. Nevertheless, THT and TBM are both leading to a slightly higher perception of danger and elicit better reaction even if there is no association with gas.

Thus it can be concluded that THT and to a lesser extend TBM are quite adequate to give the characteristic odour that people are expecting for gas. Although S-Free® is slightly more efficient than the control odour as for being associated with gas it is often confused with other odours and does not give much more sense of danger nor lead to adequate actions than the control odour.

As the identification of the different smells to the *gas smell* are not different for gas users and non gas users it seems that no bias has been introduced unless one assumes that all French people have the same proximity with THT as the gas smell regardless of the fact that there are using natural gas or not. To test that hypothesis it would be useful to conduct a similar study in other countries where gas could be odorised with different odorants.

References

1. ISO TS 16922 "Natural gas — Guidelines for odorizing gases"
2. UNI 7133, "Gas odorisation for domestic and similar uses – Procedures, characteristics and tests", Italian standard.
3. Cagnon F., Hagge E., Heimlich F., Kaesler H., Kuiper Van Loo E., Lopez Zurita J.M., Rijnaarts S., Robinson C., Salati E. and Vinck H., “New testing method helps optimize odorization levels”, IGT Symposium, Chicago 2000.
4. Cagnon F., Louvat A., Coffinet-Laguerre D., Maxeiner B., "Olfactory evaluation of the smell of a gas: A round Robin test based on the AFG Specification", Natural gas odorisation conference, Houston 2010.
5. Graf F., Kröger K., Reimert R., " Sulfur-Free Odorization with Gasodor S-Free: A Review of the Accompanying Research and Development Activities ", Energy & Fuels 2007, 21, 3322–3333.
6. Schunk C., Bernhart M., Reimert R., "Schwefelfreies Odoriermittel – Steigerung der Umweltfreundlichkeit unter Wahrung des Sicherheitsniveaus", Gas-Erdgas, 140 (1999) Nr. 10.