GI-OD-16-06
18/07/2016

Odorisation in Europe: the MARCOGAZ overview

Authors: E. Salati, W. Borghols, A. Casola, Q. Degroote, J. Dehaeseleer, F. Humhal, H. Kaesler, U. Klaas, A. Louvat, B. Metz, J. Pardinas, H. Vinck

1) MARCOGAZ

MARCOGAZ (Technical Association of the European Natural Gas Industry) is a non-profit International Association, created in 1968, which developed over the years a solid and efficient reputation with the official bodies in the European Union and other influential partners.

MARCOGAZ chief mission is to serve its Members as the European platform for any technical issue regarding natural gas.

As a representative organisation of the European Natural Gas Industry, it aims at monitoring and taking influence when needed on European technical regulation, standardisation and certification with respect to safety and integrity of gas systems and equipment and rational use of energy.

Environment, health and safety issues related to natural gas systems and utilisation are also of great importance for MARCOGAZ.

Picture 1

MARCOGAZ Working Group Odorisation is dealing with technical issues concerning the odorisation of the distributed natural gas and is active in collecting information from several EU Countries to share knowledge on the odorisation process. A table on the "Natural Gas odorisation practices in Europe" is periodically updated and can be freely downloaded from the MARCOGAZ website (www.marcogaz.org). This table contains information from 19 European Countries on different items: legal aspects, verification, plants, required concentrations and odorants' composition, odorisation costs and on methods & instruments to check the odorisation. In this paper, an overview will be represented of several of these subjects.

2) Odorisation in EU

2.1) Odorisation processes

From the periodical MARCOGAZ screening on odorisation processes, it can be observed that there are differences in odorisation practices between the EU Countries. First of all, in some Countries the gas is odorised on the transit or transmission network (Centralized Odorisation) while others are only odorising gas when it enters the distribution network (Local Odorisation).

As can be seen in Table 1, Centralized Odorisation is performed in 4 Countries (ES – even if partial – FR, HU and IE), where the other 15 Countries odorise locally, downstream the transmission pipelines.

Table 1

Country	Odorisation required on Transit (network transmitting gas, generally connected to other big network or infrastructure as storages)	Odorisation required on transport (network transmitting gas to distribution network, sometime identified as regional transport)	Odorisation required on distribution (gas delivery to domestic customers)
AT	No	No	Yes
BE	No	No	Yes
CH	No	No	Yes
CZ	No	No	Yes
DE	No	Only few transport systems are odorised, mostly using sulphur free odorant	Yes
DK	No	No	Yes
EL	No	Yes	Yes
ES	Yes	Yes	Yes
FR	Not defined	No, but the law requires that transmission companies deliver odorised gas to all customers (industrial and distributors), so the current practice is that all transported gas is odorized.	Yes
HU	No	No	Yes, but performed by Transmission companies
IE	Yes	Yes	Yes
IT	No	The gas transmission network is not odorised except for the gas delivered to the domestic customers and premises directly connected with them	Yes
NL	No	No	Yes
NO	No	No	Yes
PL	No	No	Yes
PT		Only the gas entering by pipeline from Spain is odorized, because in Spain the odorisation in transport is mandatory.	Yes
RO		Yes	No
SK	No	No	Yes
UK	No	No	Yes

2.2) Odorisation plants

Usually electronic or pneumatic pumps are used. The difference between these two technologies is depending on how the injection is steered: with an electronic pump, the injection is powered by a mechanical system, while with a pneumatic pump, the injection is assured by a difference of pressure. Sometimes a bypass system (based on partial flow from the stream of the natural gas through the odorant tank, without need of electrical power) is foreseen in case of failure of the main system. More information is listed in Table 2.

Table 2

Country	Where are the injection plants?	Number of plants	Use of Electronic pump	Use of Pneumatic pump	Use of Bypass
AT	Transport and City Gate	About 300	Yes	Yes	Yes
BE	City Gate	+/- 150	Yes	No	No
CH	Transport	Not communicated	Yes	Yes	Yes
CZ	Pressure reduction station from transmission to distribution	Approx. 100	Yes	No	No
DE	HP 16-70 bar City gate: 0-16 bar	Not communicated	Yes	Generally not, but exceptions, e.g. LNG stations, may exist	No
DK	Pressure reduction station from transmission to distribution	45	Yes	No	No
EL	City Gate	Not communicated	Yes	No	No
ES	Transport and City Gate	7 + ≈ 300	Yes	No	No
FR	Transit (Excepted 30 km pipeline in the North of France)	7 (main stations at entry point of transmission network, operating continuously) + 13 (re-odorising stations at the exit of underground storages operating only when emitting)	Yes	No	No
HU	Transit	14 central at transmission node, 100 at exit points	Yes	No	No
IE	Entering Transmission. Systems	Not communicated	Yes	No	No
IT	Transport and City Gate	> 1250	Yes	Yes	Yes
NL	Transport and City Gate	80 + 50	Yes	No	No
NO	4 bar	Not communicated	Yes	No	No
PL	Transport	Not communicated	Yes	Yes	Yes
PT	Leaving National Transport System	84	Yes	No	No
RO	0 – 10 bar	Not communicated	Yes	No	Yes
SK	City Gate	ca 1600	Yes	No	No
UK	Leaving National Transmission	49 Distribution	No	Yes	No

2.3) Requirements

Smell (measured as olfactive degree, usually expressed in the 5 degrees Sales scale, sometimes in other scales) is the typical requirement for Odorisation.

However, in Europe, the requirement is mostly expressed as a minimum odorant concentration. The reason is that an odorant concentration is easier and cheaper to check and to document than a smell.

Six Countries have smell as primary requirement. In the other Countries the requirement is a value of odorant concentration, derived from the odor intensity curve of the odorants in air.

In one Country (Italy) the concentrations are stated with olfactory tests on odorant in actual distributed gases, to take into account possible masking effects from the minor components of natural gas, such as natural sulphides or mercaptans. In Italy, there is a large variety of supplied gases: Russian, North gas, Algerian, Libyan, from national production and LNGs.

The new scenario of biomethane injection into natural gas grids gives a new interest on possible masking effects, since the upgrading process may leave some odoriferous trace components, not known by the Gas Industry. See Table 3 for the list of different requirement in EU Countries.

Table 3

Country	Is a Level of concentration/ olfactory sensation Required? (Yes or Not)	If Yes, please specify the requirement (i.e.: minimum concentration or olfactory degree)	Control required	Requirements specified standards or codes
AT	Yes	Minimum concentration	Yes	ÖVGW G 79 EN ISO 13734
BE	No	-	Yes	Synergrid recommendation 2000.50.32
CH	Yes	Minimum concentration	Yes	SVGW G 11
CZ	Yes	Olfactory degree (Level 3, Table 1, A 3, TPG 918 01)	Yes	TPG 918 01, TPG 905 01 (codes of practice)
DE	Yes	Minimum concentration	Yes	DVGW G 280-1 EN ISO 13734
DK	Yes	Minimum concentration	Yes	DVGW G 280 GR-A (Danish Gas Code)
EL	Yes	Minimum concentration	Yes	National Regulation 1712/06
ES	Yes	Minimum concentration	Yes	NGTS Code and R.D. 919/2006
FR	No	-	Yes	Arrêté 13 juillet 2000 (law), RSDG 10 (Industry requirement), Décret n°2004-251 du 19/03/2004 (law)
HU	Yes	Minimum concentration	Yes	MSZ-09-74011/5-84
IE	Yes	Olfactory degree (Level 2 Sales)	Yes	Code of Operations
IT	Yes	Minimum concentration for odorant and gases included into UNI CIG 7133; Olfactory degree (Level 2 Sales) for odorant and gases not included into UNI CIG 7133.	Yes	UNI CIG 7133 UNI CIG 9463 Dir ARG/Gas 574/13
NL	Yes	Minimum concentration (10 – 40 mg THT/m^3(n))	No	National Regulation Regeling gaskwaliteit (WJZ/13196684)
NO	Yes	Minimum concentration	Yes	No
PL	Yes	Olfactory degree	Yes	National Regulation Dz.U. 2010, No 133, 89 PN-C-04751:2011 PN-C-04753:2011
PT	Yes	Technical Regulation: Olfactory degree TSO Standard: Minimum concentration (20-24 mg THT/m^3(n))	Yes	DVGW G 280
RO	Yes	Olfactory degree (Level 2 Sales)	Yes	SR 13406 (Natural Gas Odorisation), SR 3317 (Natural Gas. Quality Requirements), EN ISO 13734
SK	Yes	Minimum concentration	Yes	TPP 918 01

Country	Is a Level of concentration/ olfactory sensation Required? (Yes or Not)	If Yes, please specify the requirement (i.e.: minimum concentration or olfactory degree)	Control required	Requirements specified standards or codes
UK	Yes	Olfactory degree (Level 2 Sales)	Yes	Gas Safety Management Regulations 1996

2.4) Odorant concentrations

The features of the odorants used in EU are reported in Table 4, while the related applied concentrations are given in Table 5. The typical concentration is the concentration that usually is injected into the natural gas guaranteeing at least the minimum concentration along the entire grid.

Table 4

Odorant	Composition %										%S
	THT Tetrahydro thiophene	**TBM Tertiary Butyl Mercaptan**	**IPM Isopropyl Mercaptan**	**NPM Normal Propyl Mercaptan**	**MES Methyl Ethyl sulfide**	**DMS Diethyl sulfide**	**EM Ethyl Mercaptan**	**Ethyl Acrylate**	**Methyl Acrylate**	**2-Ethyl-3-Methylpyrazin**	
Formula	C_4H_8S	$C_4H_{10}S$	C_3H_8S	C_3H_8S	C_3H_8S	C_2H_6S	C_2H_6S	$C_5H_8O_2$	$C_4H_6O_2$	$C_7H_{10}N_2$	
Molecular weight	**88,2**	**90,2**	**76,2**	**76,2**	**76,2**	**62,1**	**62,1**	**100,1**	**86,1**	**122,2**	
Sulphur Free								66 %	32 %	2 %	0,0
THT+ EA (Ethyl Acrylate)	12 %							88 %			4,4
THT+TBM	70 %	30 %									36,1
THT	100 %										36,4
TBM+IPM+NPM		76 %	16 %	8 %							37,1
TBM+MES		80 %			20 %						36,9
TBM+DMS (UK+IE)		80 %				20 %					38,8
TBM+DMS (CZ)		65 %				35 %					41,2
EM							100 %				51,6

Table 5

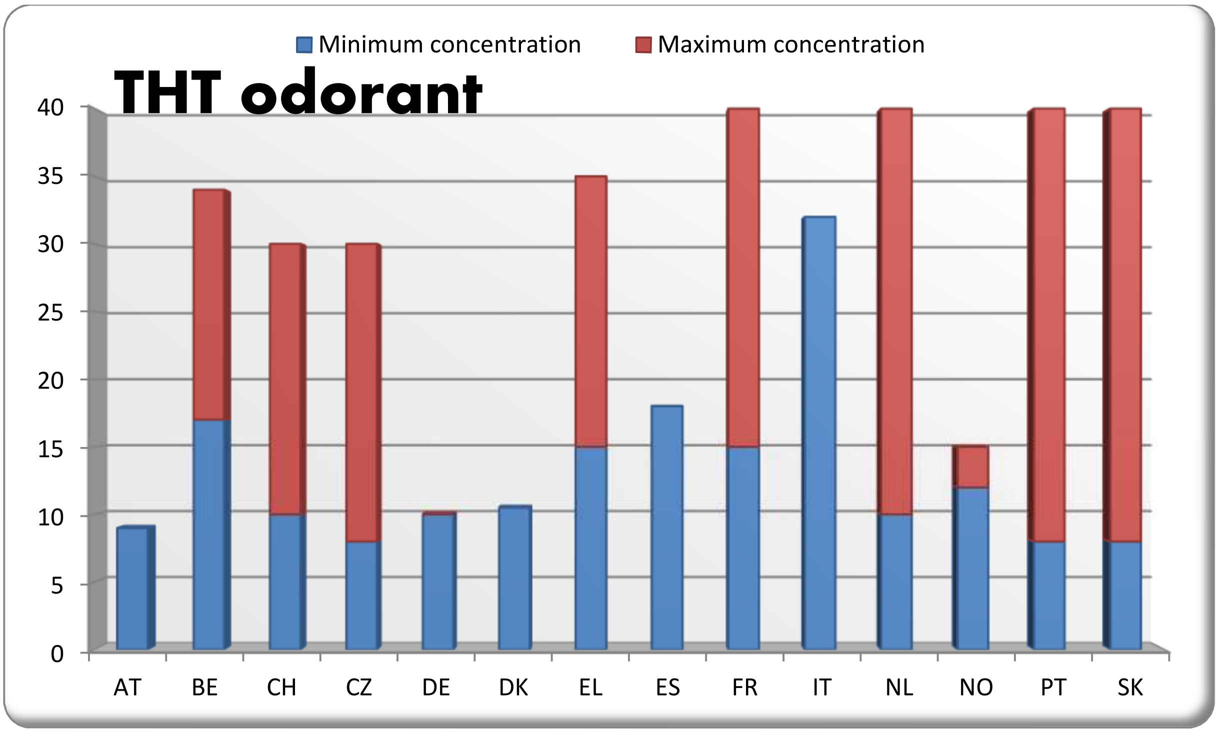
Country	Odorant	Percent consumption (%)	Minimum concentration (mg/m³)	Maximum concentration (mg/m³)	Typical concentration (mg/m³)	Unit (Standard or Normal mg/m³)
AT	THT Other odorants Sulphur Free Odorant	93% 5% 2%	9,0 - 8,0	As required at the endpoint	12-14 - 10	Normal
BE	THT TBM+IPM+NPM	-	17 5,4	34 7,1	20 6	Normal
CH	THT S-Free Acrylate	100%	10 8.8	30	15-30 12 14	Normal
CZ	THT TBM+DMS Gasodor S-free	10% 89% 1%	8 5 8	30 30 9	12 10 8,8	Normal
DE	THT Other odorants mixtures THT + EA Sulphur Free Odorant Mercaptan mixture	55 – 70% 2% - 25% 15-17%	10 Not specified 6 8 3	Not specified Not specified Not specified Not specified Not specified	15 – 18 - 11 - 15 11 – 15 5-8	Normal
DK	THT	100%	10,5 (at consumer location)	Not specified	11-17	Normal
EL	THT	100%	15	35	20	Normal

Country	Odorant	Percent consumption (%)	Minimum concentration (mg/m³)	Maximum concentration (mg/m³)	Typical concentration (mg/m³)	Unit (Standard or Normal mg/m³)
ES	THT	100%	15-trans. 18-dist.	Not specified	22	Normal
FR	THT	100%	15	40	25	Normal
HU	THT + TBM	100%	13	25	16	(?)
IE	TBM+DMS	100%	3	10	6	Standard
IT	THT TBM+IPM+NPM Sulphur Free Odorant	50% 50% -	32 9,3 (as TBM) 12,2 (total) 24,1 (as basis for further studies)	As required at the endpoint	-	Standard
NL	THT	100%	10	40	18	Normal
NO	THT	100%	12	15	-	Not known
PL	THT	100 %	Not specified	Not specified	25	Standard
PT	THT	100%	8	40	24	Normal
RO	EM	100%	3	30	8	Not known
SK	THT TBM(80%)+MES(20%)	59 % 41 %	8 mg/Nm3 5 mg/Nm3	40 15	18 10	Normal
UK	TBM+DMS	100%	5	8	6	Standard

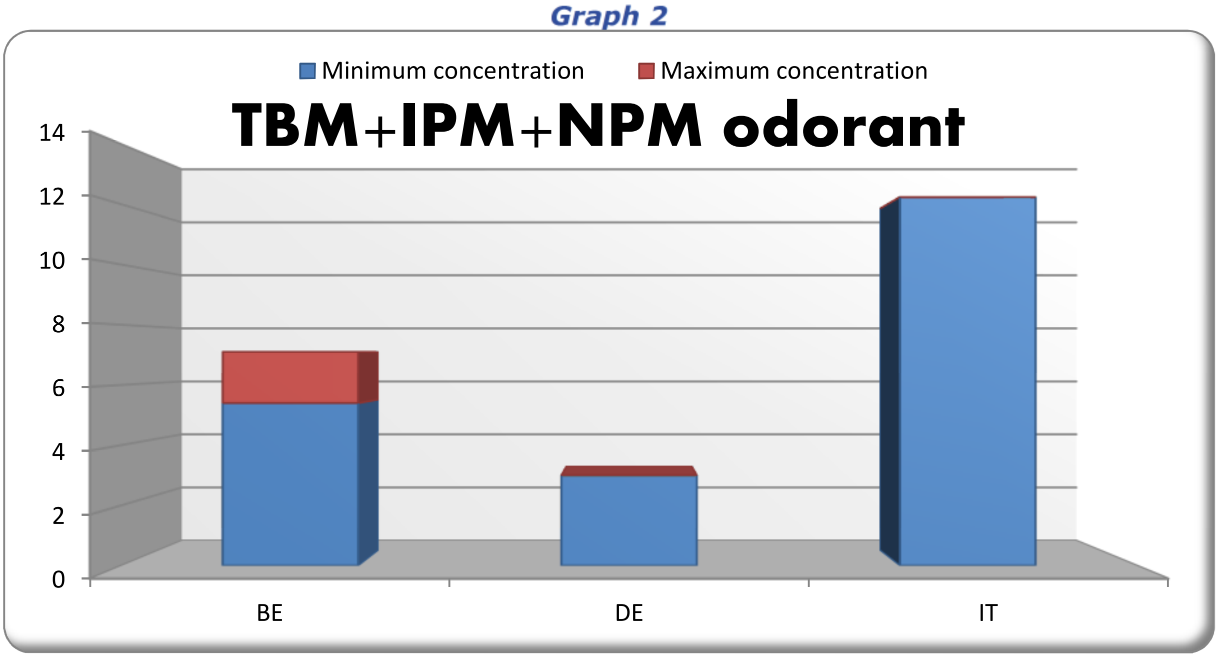
The next graphs present the differences in applied concentrations for the same odorants in different EU Countries, due to different procedures to determine them. The most used odorant is THT (Graph 1), followed by Sulphur Free (Graph 2), TBM+DMS (Graph 3) and TBM+IPM+NPM (Graph 4).

THT is broadly used; the differences of the minimum concentrations applied in the different countries are related to the different procedures used to determine them.

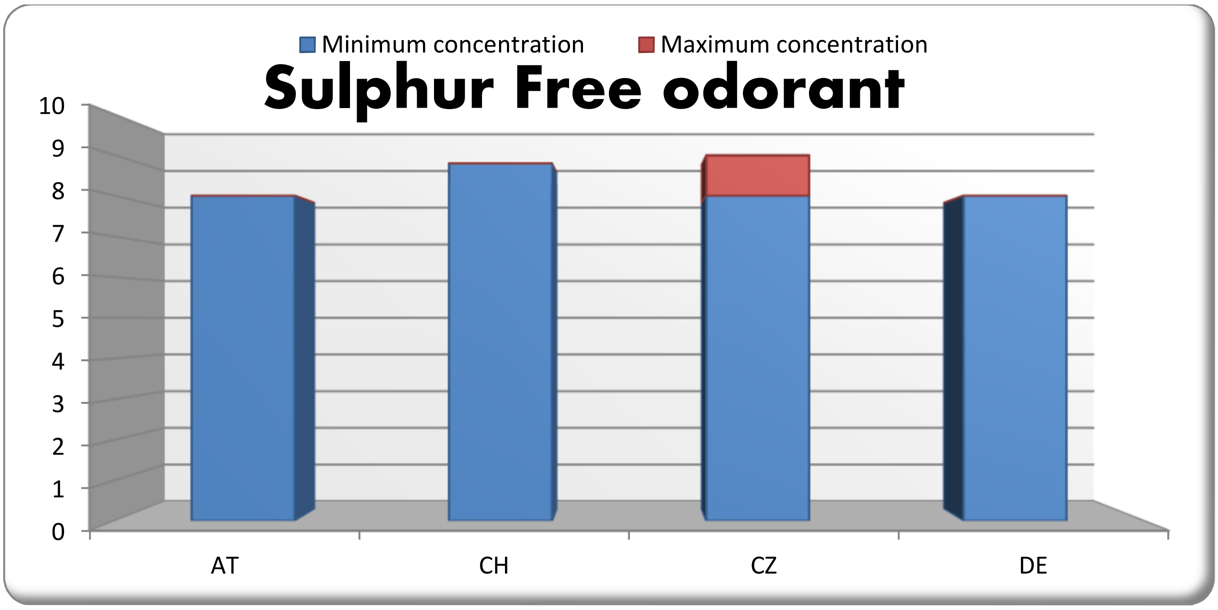
Graph 1



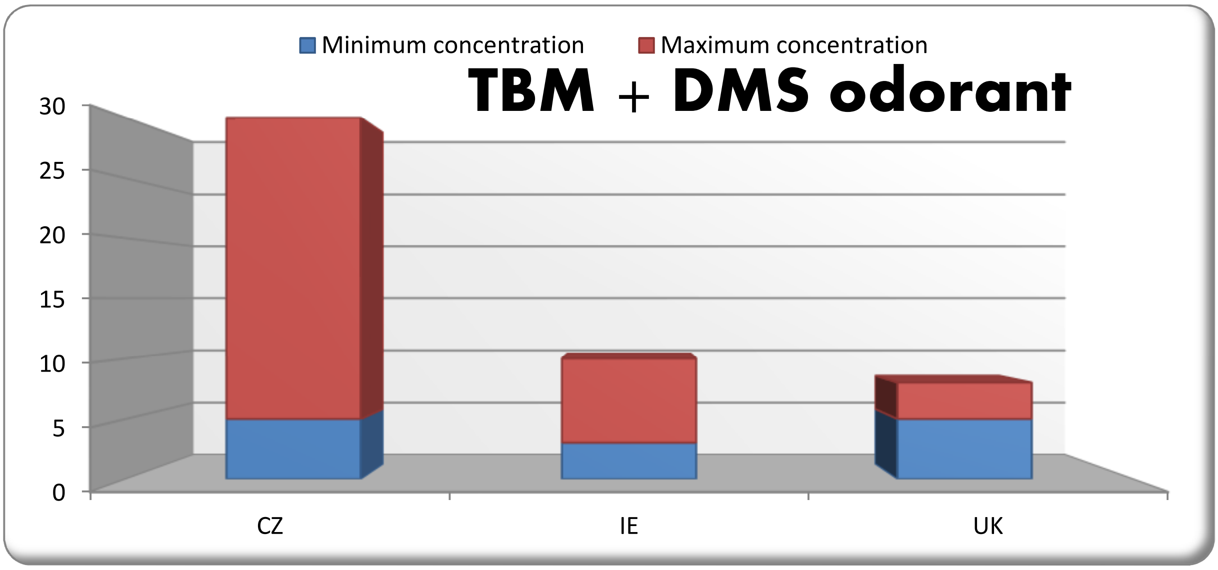
Graph 2



Graph 3



Graph 4



2.5) Odorisation control

The modalities and frequencies of the odorisation controls are reported in Table 6. Olfactory tests are recognized in 7 Countries, but only in 4 Countries they are the primary method. Gas chromatographic analyses are widely used (see Table 7).

Table 6

Country	Control on Transit	Control on Transport	Control on Distribution	Exact location of the control (end point of the pipe, or furthest location from injection point, entry point of the pipes, odorisation station...).	Frequency: continuous (CI) or periodical inspection (P)
AT	No	No	Yes	End point of pipe	yearly
BE	No	No	Yes	Pressure station MP/LP & LP grid (End point of pipe)	P (min./ 3 months)
CH	Yes	No	Yes	Before the entry in distribution system	P (min. 4 times / year)
CZ	No	No	Yes	Exit point and distribution system (fixed points)	P / 6 months
DE	No	No	Yes	End point of pipe	P (2 x p.a.) *Sometime CI near injection*
DK	No	No	Yes	At fixed strategic points. They are located far from the dosing plants.	P (2 times per year)
EL	No	No	Yes	City gates and network points at random (especially the most remote ones from the odorant injection points)	P
ES	Yes	No	Yes	In distribution: city gate and end point of the pipe	CI P (1/month)
FR	Not defined	Yes	Yes	Transport: At odorisation station (entry points) + ≈ 25 locations on network Distribution: Random locations on network (100/year)	CI. (Transport) P (Distribution)
HU	No	Yes	No	Exit point and distribution system	CI - P
IE	Yes	Yes	No	Entry point	P (Monthly)
IT	No	The gas transmission network is not odorised except for the gas delivered to the not-industrial customers and premises directly connected with transmission network	Yes	End point of the pipe, and odorisation station	6 months
NL	No	No	Yes	City gate station, Odorisation station	P (3 weeks)
NO	No	No	Yes	-	P
PL	No	No	Yes	End point of the pipe, pressure stations MP/LP	P (2 weeks) Ci
PT	No	Yes	No	End point of pressure regulating and metering stations HP/MP	CI and P (monthly)
RO	No	Yes	Yes	-	P/ 3 monts
SK	No	No	Yes	Selected points of transport pipes and end point of the distribution system	CI – P, 6-months
UK	No	No	Yes	Leaving the transmission system	CI – P

Table 7

Country	Who asks for the control (regulation, voluntary)	Who does work the control (third part or not)	What is controlled (odorant concentration, smell, etc.)	Controlled by Olfaction	Controlled by gas chromatography	Controlled by chemical sensor	Controlled by odorant consumption

Country	Who asks for the control (regulation, voluntary)	Who does work the control (third part or not)	What is controlled (odorant concentration, smell, etc.)	Controlled by Olfaction	Controlled by gas chromatography	Controlled by chemical sensor	Controlled by odorant consumption
AT	Legal requirement	Grid operator	Odorant concentration	No	Yes	Yes	Yes
BE	Legal requirement (Royal Decree 28.06.1971)	Third party	Odorant concentration	No	Yes	No	Yes: visual inspection and calculation of odorant concentration
CH	Technical rules (SVGW G11)	Third party	Odorant concentra-tion	No	Yes	No	No
CZ	Technical rules (TPG 918 01, TPG 905,01)	DSO	Smell and Odorant concentration	Yes	Yes	Yes	Yes
DE	Legal requirement Technical rules (DVGW G 280-1)	Grid operator	Smell and Odorant concentration	Yes	Yes (legal)	Yes	Yes
DK	Regulation (Danish Safety Technology Authority)	Grid Operator	Odorant concentration	No	Yes	No	Yes, the odorant consumption is monitored continuously
EL	Regulation	DSO	Odorant concentration	No	Yes	No	No
ES	Legal (Government)	DSO (CI) and third part (P)	Odorant concentration	No	Yes	Yes	No
FR	Regulation (Transport) Voluntary (Distribution)	Grid Operator	Odorant concentration	No	No	Yes	No
HU	Regulation	Third party	Odorant concentration	No	No	No	Yes
IE	Technical rules (Code of Operations)	TSO/Third Party	Odorant concentration	No	No	No	Yes
IT	Legal (Law 1083/71) Regulation (ARG/Gas 574/13)	Grid operator	Odorant concentration, Smell (legally accepted, but AEEGSI (Regulatory Body), considers only gas chromatographic determinations	Yes	Yes	No	No (only for odorisation plants check)
NL	Regulation	Grid operator	Odorant concentration	No	Yes	No	Yes
NO	Voluntary	Grid operator	Odorant concentration	No	Yes	No	No
PL	Technical rules Dz.U. 2010, No 133, 39 PN-C-04751:2011 PN-C-04753:2011)	DSO and/or grid operator	Smell and/or Odorant concentration	Yes: Olfactory is primary method	Yes	Yes (indicative measurements)	Yes
PT	Voluntary	TSO (O&M Department)	Odorant concentration	No	No	Yes	Yes
RO	Technical rules (SR 13406 SR 3317)	Grid operator	Smell and Odorant concentration	Yes: Olfactory is primary method	Yes	Yes	No
SK	Legal	DSO	Smell and Odorant	Yes: Olfactory is	No	Yes	No

Country	Who asks for the control (regulation, voluntary)	Who does work the control (third part or not)	What is controlled (odorant concentration, smell, etc.)	Controlled by Olfaction	Controlled by gas chromatography	Controlled by chemical sensor	Controlled by odorant consumption
	requirement (State legislation)		concentration	primary method			
UK	Regulation	DSO	Smell	Yes: Olfactory is primary method	No, only when required	No	Continuously monitored

At the end of 2013, the MARCOGAZ Working Group Odorisation started a survey on odorisation analysis, aiming to know the similarity and differences in methods utilised for odorant analysis in natural gas (olfactory analyses were out of the scope of that survey). A questionnaire was sent to the MARCOGAZ Members to collect this information. 9 answers, including 2 from Italy, were received from 8 Countries (BE, CZ, EL, ES, FR, IT, NL and RO).

Five answers are dealing with portable microGC (compact gaschromatographs using micro-thermal conductivity detectors [micro TCD detectors]); two answers are referring to sulphur dedicated gas chromatographs equipped with a Flame Photometric Detector [FPD]. Sensors are described in two cases.

It must be noted that the difference between gas chromatographs and sensors is remarkable. Gas chromatographs can achieve better accuracy, reproducibility and documentation than sensors. In contrast to gas chromatographs, sensors cannot separate the different compounds present in the sample. The accuracy is only expressed for the gas chromatographs. In fact, sensors are often considered as "indicators", giving results without traceability to a recognized reference measuring system.
The differences between microGC (using micro TCD detectors) and sulphur dedicated gas chromatographs are listed as below:

- microGC is often used for its functional aspects: it is very easy to transport it outside the laboratory and it is very fast in analysing. On the other hand, its sensitivity is limited and its detector (the micro-TCD) is not selective so that possible interferences are more than with Sulphur dedicated gas chromatographs. A microGC can also be used as fixed gas chromatographs.
- Sulphur dedicated gas chromatographs (equipped with FPD or other detectors dedicated to sulphur analysis) are laboratory instruments with better analytical performances. They are not built for on-site analyses. To use them on the grid, it is necessary to install them into a dedicated van. The sensitivity is higher and they can analyse a wider range of sulphur compounds. Normally, the analysis will be longer than with a MicroGC.

It is possible to use a laboratory gas chromatograph for odorisation analysis via remote sampling and fast transportation. Usually lab analyses are performed for special aims (e.g. for legal purposes) or when a better accuracy is needed. The most delicate part is the sampling procedure since the odorant can be adsorbed/oxidized and the sample can be contaminated by air.

On site analyses with fixed gas chromatographs are used when specific grid points must be continuously checked, while the use of portable gas chromatographs is common when several points must be periodically checked.

In general, the methodologies are considered satisfactory and no need of improvement was pointed out. The compliance of the analysis results is given by direct comparison with the range of admissible values of concentration (referring to applicable rules).

More information on the different methodologies is given in the following tables.

Table 8: Portable microGC with microTCD

Analytical method (standard):	ISO 19739 and national standard.
Carrier:	Helium
Analytes:	THT and TBM
Number of analyses to stabilize the gaschromatograph before the measurement:	5, or until a fixed value of standard deviation is achieved.
Number of repetitions for a single result:	Range from 3 to 10.
Acceptance criteria of the results:	Not always they are specified. When they are, the criteria is related to evaluation of the standard deviation.
Range of analizable concentrations:	The range is variable, depending on the calibration and on the national requirement. The wider range is 1-200 mg/m^3 for THT and 1-100 mg/m^3 for TBM.
Uncertainty achieved by the Lab:	THT: 10% (at 20-35 mg/m^3) TBM: 13% (at 9 mg/m^3)
Calibration (levels):	Usually 3
Calibration (periodicity):	At least monthly
Sampling points locations:	Odorisation plants (city gate distribution station); Relevant points of the grid (determined by the distribution grid operators); End points of the grid (especially on ramifications of the primary pipeline).

Table 9: Fixed (process) microGC with microTCD

Analytical method (standard):	ISO 19739 and national standard.
Carrier:	Helium
Analytes:	THT, H_2S, COS, MM, TBM
Number of analyses to stabilize the gaschromatograph before the measurement:	Not applicable: continuous control.
Number of repetitions for a single result:	1.
Acceptance criteria of the results:	Reproducibility, in one case.
Range of analizable concentrations:	THT: (5-10)–200 mg/m^3 Not specified for other sulphur compounds.
Uncertainty achieved by the Lab:	THT: ±3mg/m^3 between 15 to 40 mg/m^3
Calibration (levels):	1
Calibration (periodicity):	The calibration is automated. It can be executed on an hours/daily or monthly basis.
Sampling points locations:	Odorisation plants, hubs of the transmission grid, critical points in

	the network.

Table 10: Laboratory gas chromatographs, even installed on vehicles (FPD - SCD detectors)

Analytical method (standard):	EN ISO 19739
Carrier:	Helium
Analytes:	THT, TBM, DMS, H_2S, COS, EM (C_2H_5SH) and other Sulphur compounds.
Number of analyses to stabilize the gaschromatograph before the measurement:	5 or until achievement of the prescribed value of standard deviation
Number of repetitions for a single result:	1 - 3
Acceptance criteria of the results:	Standard deviation.
Range of analizable concentrations:	THT: from 0,01 – 0,1 to 100 mg/m^3 TBM: from 0,5 – 1 to 100 mg/m^3
Uncertainty achieved by the Lab:	Not known
Calibration (levels):	From 1 to 3
Calibration (periodicity):	Before every analysis cycle 6 months
Sampling points locations:	End points and relevant points of the grid - especially on ramifications of the primary pipeline and at city gates and at main distribution stations.

Table 11: On site sensors (Electrochemical detectors)

Analytical method (standard):	The method is not described in standard.
Carrier:	-
Analytes:	THT, TBM, Sulphur-free odorant, EM, H_2S.
Number of repetitions for a single result:	-
Acceptance criteria of the results:	Repeatability
Range of analizable concentrations:	THT: 0-100 mg/m^3; TBM: 0-3,6 mg/m^3; Sulphur-free odorant: 0-8 mg/m^3; EM: 0-30 mg/m^3; H_2S: 0-141 mg/m^3.
Uncertainty achieved by the Lab:	-
Calibration (levels):	For the calibration, a test gas is required containing the odorant to be detected in the same range of concentration
Calibration (periodicity):	A calibration must be performed on each day of measurement
Analysis locations:	Relevant points on site after Odorisation. Endpoints of the grid, especially on ramifications of the primary pipeline and at city gates and at main distribution stations.

3) Sulphur and odorants

Recently, the sulphur content related to odorants in natural gas is under discussion in Europe regarding the exchange of odorised gas between the different Countries, and regarding the request from some national governments and also from producers of gas applications to reduce the quantity of sulphur from odorants.

The content of sulphur in the odorant molecule can be quoted from 0% (Sulphur Free odorants) to 35-40% with the usual odorants (see Table 4).

Taking into account the typical concentrations of the odorants in EU Countries (see Table 5), the theoretical concentration of total sulphur and of the mercaptan sulphur deriving from odorants in natural gas, can be calculated. (see Tables 12 and 13)

Not considering the sulphur free odorant, when a maximum concentration for odorants is expressed, the values of:

- total sulphur from odorants in the natural gas is less than 15 mg/m^3 (n), with typical values of less than 10 mg/m^3 (n),
- mercaptan sulphur is less than 4 mg/m^3 (n), with typical values less than 2-3 mg/m^3 (n).

Table 12: Total Sulphur from odorants (Sulphur Free excluded)

Country	Odorant	Minimum Sulphur concentration (mg/m3) (n)	Maximum Sulphur concentration (mg/m3) (n)	Typical Sulphur concentration (mg/m3) (n)
AT	THT	3,3	-	4,7
BE	THT	6,2	12,4	7,3
BE	TBM+IPM+NPM	2,0	2,6	2,2
CH	THT	3,6	10,9	8,2
CZ	THT	2,9	10,9	4,4
CZ	TBM+DMS	2,1	12,4	4,1
DE	THT	3,6	-	6,0
DE	THT + EA	0,3	-	0,6
DE	TBM+IPM+NPM	1,1	-	2,4

Country	Odorant	Minimum Sulphur concentration (mg/m3) (n)	Maximum Sulphur concentration (mg/m3) (n)	Typical Sulphur concentration (mg/m3) (n)
DK	THT	3,8	-	5,1
EL	THT	5,5	12,7	7,3
ES	THT	6,5	-	8,0
FR	THT	5,5	14,5	9,1
HU	THT + TBM	4,7	9,0	5,8
IE	TBM+DMS	1,2	3,9	2,3
IT	THT	12,3	-	14,7
IT	TBM+IPM+NPM	4,8	-	5,8
NL	THT	3,6	14,5	6,5
NO	THT	4,4	5,5	5,2
PL	THT	-	-	9,1
PT	THT	2,9	14,5	8,7

Table 13: Mercaptan Sulphur from odorants (only odorants containing mercaptans)

Country	Odorant	Minimum Sulphur concentration (mg/m3) (n)	Maximum Sulphur concentration (mg/m3) (n)	Typical Sulphur concentration (mg/m3) (n)
BE	TBM+IPM+NPM	2,0	2,6	2,2
CZ	TBM+DMS	1,3	8,0	2,7
DE	TBM+IPM+NPM	1,1	-	2,4
HU	THT + TBM	1,4	2,7	1,7
IE	TBM+DMS	0,9	3,1	1,9
IT	TBM+IPM+NPM	4,8	-	5,8
RO	EM	1,5	15,5	4,1
SK	TBM (80%) + MES (20%)	1,5	4,4	2,9
UK	TBM+DMS	1,6	2,6	2,0

3.1) Exchange of odorised gas

Flows of gas between EU Countries normally are not odorized, except from:

- UK to Ireland;
- France to Switzerland/Italy and Spain;
- Spain to Portugal and France.

Some exchange of odorised gas may anyway occur due to local connections between networks. This is known to happen between France and Luxembourg, France and Switzerland, Hungary and Austria, for instance.

In 1998, when the Interconnector was taken into service, the UK changed its odorisation practices allowing the transfer of natural gas to Belgium without added odorant at the cross-border points.

As far as regards transmission of gas between EU Countries, decentralized odorisation could be preferred because it avoids the addition of sulphur from odorisation to transmitted natural gas. In the case of centralized odorisation, the adoption of sulphur free odorant could be helpful to maintain low levels of sulphur in the gas transmitted between EU Countries.

3.2) Masking effects

Usually no masking effects are reported from mixture of different sulphur odorants, even if it can hypothesize some effects of enhancement of the odour in mixtures between sulphides and mercaptans (for example in mixtures containing TBM and MES) which make it difficult to predict the strength of smell of the mixture. In case of mixtures of Sulphur odorants and sulphur free odorants, no public data are available yet and it could be necessary to perform olfactory tests to get some insight on the behaviour of the mixture in terms of odour.

4) Odorisation costs in EU

In 2013, a questionnaire was sent to the Members of the WG Odorisation, to collect information on odorisation costs. Answers were received from 9 (BE, CZ, DE, EL, ES, FR, IT, NL, RO) Countries.

The result is split into two sections: centralized (Transmission) and local (Distribution) odorisation.

4.1) Centralized Odorisation costs

The three answers received, referred to transmission grids smaller than 4.000 km till longer than 35.000 km, with an amount of odorized gas between 4 and more than 55 billions of cubic meters of natural gas transported per year.

Plants: usually injection systems are used. The number of plants is very variable, from 1 every 25-30 km to 1 every 2.000 km. The estimated cost of a plant is comprised between 20.000 and 100.000 €, depending on the size. The estimated operational cost (excluded odorant purchase) is between 1.000 and 5.000 €/year.

Odorants: the costs of the odorant is depending on the delivery method, where delivery by drums is about 40% cheaper than by safety barrel (in this case the cost is about 10 €/kg).

Controls: the cost depends on the odorant analysis method:

- with fixed gas chromatographs (usually the apparatus includes local and remote alarm in the case of instrument's failure or low concentrations of odorant, sometimes with feedback to the plants to increase odorant injection) can be estimated between 50 and 75.000 € per analyser.
- with portable microGC utilized at variable points (every 300 - 700 km) on the grid by an operator; the cost of one microGC is around 30.000 €. In some cases analysers are located at the odorisation plants.

4.2) Local Odorisation costs

The six answers received, referred to distribution grids between 5.500 km and 125.000 km, with an amount of odorized gas between 1,5 and 25 billions of cubic meters of natural gas distributed per year.

Plants: both injection systems and by-pass systems are used. The injection systems can be constituted by pumps or tank pressurized injection systems. The number of plants is variable from 1 every 85 km to 1 every 1000 km. The estimated cost of a plants is between 10.000 and 130.000 €, depending on type and size. For injection systems, the operational costs are between 550 and 12.500 €/year. One answer reports a quantification of 15 - 30 working hours per year for each plant. The cost of the By-pass odorizers is between 10.000 and 30.000 € per plant. No electronic devices are needed for this kind of apparatus and the operational costs are limited to extraordinary maintenance.

Odorants: the costs of the odorant vary from 5 to 18 €/kg (usually, the higher prices include refilling/maintenance).

Controls: usually the analyses are performed with portable or transportable gas chromatographs (25.000 - 30.000 €). The cost of 1 analysis can be estimated as about 2 working hours when performed by internal personnel (only analysis – not travel and excluding the cost of the instruments investment).

Two answers report the quotation of checking with odorant sensors (cost between 2.000 € and 4.500 €), performed by internal personnel: about 30 minutes of working hours per point.

4.3) Relevant considerations

The costs are highly influenced by:

- Configuration of the grid: dimension, shape, consumptions, location of the connections of the customers (usually to the distribution grid; sometimes directly to the transmission grids), etc;
- Type and size of plants and their remote monitoring;
- Requested odorant concentrations;
- Frequency of the odorisation controls;
- Special constraints by law and/or National Authorities.

5) Recent activities of MARCOGAZ WG Odorisation

Following recent developments in the Gas Industry, the WG is studying which influence they have on the odorisation activity:

- Odorisation of small flow grids or small flow gas injection sites (e.g. injection of biomethane, small LNG grid);
- Odorisation of CNG for vehicles;
- Online odorant concentration measuring system.

The WG prepared, too, a list of international standards related to odorisation and a biographical collection of work on Odorisation.

6) Conclusions

In every Country, odorisation of distributed gases is required for safety reasons. Although the formulation may vary, the basis of the requirements is that the smell shall be perceived before a given concentration of gas in air.

To obtain this result, different technical approaches are possible.

MARCOGAZ Working Group Odorisation is a European platform where these practices concerning the used odorant, odorisation plants, injections, measurements, surveys,…are collected from several EU Countries to share knowledge on the odorisation process.

This knowledge is of great interest for all parties looking to improve their practices technically, economically and/or legally. It should bring to a better homogeneity in the odorisation process within EU and beyond.