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# VOC Vapour Recovery Controls and Technology

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**Abstract:** ***This article explores the complex technical implementation of the petrol vapour cycle in the European Union, focusing on the recovery of volatile organic compounds VOCs during the transport and storage of petrol. The legal framework, including directives such as Stage I and Stage II petrol directives, plays a crucialrole in reducing VOC emissions. Additionally, theuse of Best Available Techniques BAT and measures to minimize petrol vapour release during storage, loading, and refuelling are discussed. The impact of these measures on air quality and resource conservation is highlighted, with significant reductions in VOC emissionsobserved over theyears. This article provides insights into the current state of the science and the potential for further improvement in VOC recovery and emission reduction efforts.***

**Keywords:** petrol vapour cycle, volatile organic compounds, VOC emissions, EU directives, Best AvailableTechniques, air quality

## 1. Introduction

Because of its relatively high vapour pressure, petrol readily enters the gas phase and reaches a relatively high saturation concentration of about 1 kg/m$^3$ (the steady-state rule of thumb). These vapours are returned from the vehicle tanks to the tank farms or refinery in the opposite direction to the transport vehicle tank, where they are liquefied. As a result, about 1 ‰ of the petrol transported can be recovered and made available again as a valuable feedstock. This completes the 'petrol vapour cycle'. In principle, this is a simple relationship, but the technical implementation is complex.

In the European Union, this recovery is achieved by:
The Phase I directive on petrol has been in force since 1994 and the Phase II directive since 2009, but the pioneer in the field, Germany, has had systems in place reliably for about two decades.

The motivation for this article is to present the current state of the science and the current state of AK-S Ltd. MKI, the motivation and results of the project, the possible further development of the project, to recall the proven techniques and to point out the remaining opportunities for improvement.

***Impact of volatile organic compounds on air pollution***
Volatile organic compounds (VOCs) are used in many technical processes and activities (e.g. painting and printing). This includes petrol vapours. These substances can be directly harmful to human health. Petrol, for example, contains the carcinogen benzene, which increases the wear resistance of the engine.

Although VOCs are often only detectable because of their smell, they are also precursors, together with nitrogen oxides, of ground-level ozone, which forms "summer smog" in strong sunlight. The harmful effects of ozone need not be mentioned: it has a negative impact on both human health and plants.

The EU Air Quality Directive [1], which in Germany is contained in the 39th BImSchV [3], includes an air quality limit value for benzene of 5 µg/m$^3$ (annual average) and a long-term ozone target value for the protection of human health (120 µg/m$^3$ as a maximum 8-hour daily average). This is still currently exceeded in many EU Member States. According to the European Environment Agency's (EEA) 2012 air quality report, in 2010, 17% of the European population lived in areas where this value was exceeded. Although non-methane VOC emissions (NMVOCs) fell by 27% in the EU between 2001 and 2010, ozone pollution has not been reduced accordingly. The EEA assessment for summer 2012 [5] shows that the long-term ozone target for the protection of human health has been exceeded in all but one EU Member State. In 17 EU Member States, the applicable ozone target of 120 µg/m$^3$ (the maximum 8-hour daily average), which can be exceeded on a maximum of 25 days, is not met (see also Figure 1.)

The following EU directives are mainly aimed at reducing VOC emissions:

- NEC Directive 2001/81/EC of 23 October 2001 on national emission ceilings for certain atmospheric pollutants [6].
- Stage I petrol Directive 94/63/EC of 20 December 1994 on the limitation of emissions of volatile organic compounds (VOCs) resulting from the storage of petrol and its distribution from petrol stations to service stations [9].
- Directive 2009/126/EC of 21 October 2009 on Stage II petrol vapour recovery during refuelling of motor vehicles at service stations [10].
- Decopaint Directive 2004/42/EC of 21 April 2004 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC [11].

The legal background to reducing petrol vapour emissions

Transposition of the Stage I petrol directive into EU law

Directive 94/63/EC of 20 December 1994 on the limitation of emissions of volatile organic compounds due to the storage of petrol and its transport from petrol stations to service stations essentially regulates:

- Transfer and storage of petrol in large and small tank farms.

- Requirements for containers for transport vehicles.
- Requirements for storage containers for tank terminals.

The then EU Member States had until 31 October 1995 to transpose this Directive into their national legislation.

The amendment of the 20th BImSchV of 24 April 2012 extended the previous scope of application beyond petrol to fuel mixtures and crude petrol. Prior to the amendment, questions were regularly raised as to the extent to which the Regulation also applies to the storage of petrol mixtures and intermediate products (as opposed to "saleable products"), in particular as they have virtually the same vapour formation potential. The inclusion of blended petrol, i.e. petrol blended with biofuels (petrol containing more than 10% bioethanol by volume) and raw petrol was therefore a logical step.

The Stage II petrol directive, Directive 2009/126/EC, aims to regulate the recovery of petrol vapour when fuelling motor vehicles. Member States had until 31 December 2011 to transpose it into national law. All service stations in Europe had to be equipped with vapour recovery systems. Because of negative experiences with the efficiency of vapour recovery systems due to technical failures or lack of maintenance (up to 30% failures in total [15], [16], [17]), the German BImSchV 21 was amended for the first time. The main objective was to measure the efficiency of the back-suction systems at each refuelling and to shut down the faulty well column in case of failure by making the use of automatic monitoring systems mandatory. This would significantly increase the efficiency of vapour recovery systems. On 24 April 2007, the Stage II petrol directive was transposed into German law by amending the BImSchV [13]. As the requirements had already been implemented in Germany well before, the Stage II petrol Directive did not lead to new requirements from a technical point of view. In accordance with EU requirements, a labelling obligation for service stations with vapour recovery systems was introduced from 01.07.2012.

***The use of BAT***

A key tool in the immission control legislation is the reference to the nationally regulated concept of "state of the art", which in the European context is equivalent to the term "best available technology" (BAT). In Europe, the BAT for each industrial installation covered by the IE Directive [8] is developed through a procedure agreed between EU Member States, industry and its associations and environmental organisations (Article 13 of the IE Directive) and set out in BAT Reference Documents (also known as BREFs - Best Available Technique Reference Documents). Parts of the BREFs are published by the European Commission as 'BAT conclusions'.

***Measures to avoid and reduce the release of petrol vapours into the atmosphere***

**Storage**

Gasoline is stored in refineries or tank farms in above-ground, flat-bottomed tanks. Fixed roof or floating roof tanks are used. These tanks have two basic requirements to minimise emissions:

They should not heat up significantly in the sun and should be built as compactas possible.

**Loading**

When filling a rigid or filling station tank, gases are displaced by the inflowing medium. In order to avoid emissions, the vapours must be displaced from the tank receiving the petrol into the sending tank against the flow of petrol (gas hose principle).

Filling of stationary and mobile containers.

Service station storage tanks shall be installed underground and filled through a discharge pipe with a connection.

Petrol is transported by road tankers, rail tankers and ships. The choice of mobile means of transport is based on economic criteria, determined in particular by the distance of the journey.

***Refuelling of motor vehicles at petrol stations***

The principle of gas gassing is also used when refuelling cars to prevent valuable petrol vapours from simply being released into the atmosphere. During refuelling, the petrol vapour escaping from the vehicle's tank is returned to the petrol station's storage tanks via a vapour recovery line from the filling nozzle to the storage tanks.

In Hungary, "active" steam recovery systems are used in accordance with the EU directive. As soon as the fuel flow starts at the gun, the petrol vapour is "actively" extracted ("vacuum vapour recovery system") and then fed into the underground tanks of the petrol station by a vacuum pump in the well column. The volumetric flow rate of the petrol vapour must be equal to the volumetric flow rate of the fuel.

In order to ensure the proper operation of the steam recovery system, since 01.01.2017 the operation of automatic control equipment is mandatory in all steam recovery systems in Hungary. This means that if ten consecutive refuelling failures occur at the filling station, an error message is displayed and after 168 hours, without correcting the fault, the well column must be shut down.

The operator shall have the requirements for the gun smoke recirculation system reviewed every 3 years by the authority and an authorised intermediate body

Impact of measures to recover petrol vapour and reduce emissions

Between 1990 and 2010, total NMVOC emissions in Germany fell from 3.1 million tonnes to less than 1.05 million tonnes, a reduction of about two-thirds.

Petrol storage losses, particularly due to the gradual installation of vapour recovery and vapour recovery systems at service stations, fell from around 150 000 tonnes in 1993 [36] to around 15 500 tonnes in 2010 [35].

Originally, the legislators hoped that the introduction of vapour recovery systems with the 21st BImSchV in 1992 would reduce VOC emissions by about 70 percent, from 60

000 tonnes in 1990 to about 20 000 tonnes in 2000 [36]. UBA estimates that the 21st BImSchV could reduce VOC emissions to below 10 000 tonnes by 2010 [37].

Due to the Stage I and Stage II Directives for petrol and the requirements of BImSchV 20-21, a significant part of the reduced VOC emissions is recovered in the form of liquid petrol and returned to the economic cycle. The "petrol vapour cycle" thus also contributes significantly to resource conservation.

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