09-10 | 2023
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Thema: Gerüche

GERÜCHE

Klassifikation von eindeutig angenehmen Anlagengerüchen

PAK

Chromatographische Methode zur Messung schwerflüchtiger PAK

VDI-HISTORIE

Mit Koffer auf den Eiffelturm – 100. Geburtstag von Heinrich Stratmann

Covid –19 restrictions expose air traffic at the Munich Airport as hotspot of ultrafine particle pollution – implications for regional air quality

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ABSTRACT The massive decline of air traffic in consequence of the Covid-19 pandemic allowed a detailed analysis of aviation induced noise and particularly air pollution caused by kerosene combustion. As expected, aircraft noise is reduced significantly particularly during daytime. Notably, the particulate matter $PM_{2.5}$ and PM_{10} officially measured as pollution load at airports is proven to be almost unchanged in ambient air. As jets do not emit coarse fine dust but solely ultrafine particles smaller than 0.1 µm (UFP), this result is no surprise. However, the dramatic reduction of ultrafine particle concentration under reduced air traffic is exemplified e.g. by 7,100 UFP/cm^3 in April 2020 while in February 2020 at the Munich Airport center still 54,200 UFP/cm^3 were measured. Assuming an UFP background concentration of 5,000 UFP/cm^3, a decline of air traffic by 93% reduced UFP by the same magnitude. Measuring the downwind plume of the airport at varying distances the number of particles decreases while the particle size increases which is based on the fact that aircrafts emit only smallest UFP which intermix with bigger UFP from other sources around the airport. Effective measures to prevent UFP emissions are urgently needed. In addition to the use of sulfur-free kerosene, towing the aircraft during all taxiing procedures is the most effective measure to reduce UFP on ground. This work fostered the development of *https://10nm.de/*, which intends to provide a simulation of the potential UFP load at any airport based on wind conditions like wind direction and wind speed.

Covid-19 Restriktionen entlarven den Flugverkehr am Flughafen München als größte Quelle der Ultrafeinstaubbelastung – Implikationen für die regionale Luftqualität

ZUSAMMENFASSUNG Der massive Rückgang des Flugverkehrs infolge der COVID-19 Pandemie ermöglichte eine detaillierte Studie über Lärm- und insbesondere Schadstoffbelastungen als Folge der Kerosinverbrennung. Wie erwartet wurde der Fluglärm vor allem tagsüber deutlich reduziert. Bemerkenswert ist, dass die Konzentration der Feinstaubpartikel $PM_{2.5}$ und PM_{10}, die offiziell als Schadstoffbelastung an Flughäfen gemessen werden, in der Umgebungsluft nahezu unverändert blieb. Weil Jets keinen groben Feinstaub emittieren, sondern ausschließlich Ultrafeinstaub (UFP) kleiner als 0,1 µm, überrascht dieses Resultat nicht. Jedoch lässt sich bei reduziertem Flugverkehr eine dramatische Reduktion der UFP-Konzentration nachweisen. So wurden im April 2020 7 100 UFP/cm^3 gemessen, während die Konzentration im Februar 2020 am Flughafen München noch 54 200 UFP/cm^3 betrug. Unterstellt man eine UFP-Hintergrundkonzentration von 5 000 UFP/cm^3, so ging der Flugverkehr mit 93 % in einer vergleichbaren Größenordnung zurück wie die UFP-Konzentration. Im Abwind des Flughafens ging die Partikelzahl zurück, während die Partikelgröße zunahm – eine Konsequenz der Tatsache, dass Flugzeuge nur kleinste UFP emittieren, die sich mit größeren UFP aus anderen Quellen um den Flughafen herum vermischen. Effektive Maßnahmen zur Vermeidung von UFP-Emissionen sind dringend erforderlich. Neben der Verwendung schwefelfreien Kerosins ist das Schleppen der Flugzeuge während aller Taxiing-Prozeduren die effektivste Maßnahme, um UFP am Boden zu vermeiden. Diese Arbeit förderte die Entwicklung von *https://10nm.de/*, die eine Simulation der potenziellen UFP-Fracht an jedem Flughafen abhängig von Windrichtung und Windgeschwindigkeit bereitstellen möchte.

1 Introduction

Air traffic restrictions as result of the SARS-CoV 2 pandemic offered a unique opportunity to correlate the burden of ultrafine particles (UFP) emissions with the frequency of air traffic. Besides noise, UFP generated by the jet engine combustion process are characteristic for aircraft specific pollution [1; 8] and the exhaust of jet engines in the breathing air. Here we use the Munich International Airport (MUC) as an example to correlate flight intensity with ultrafine particle pollution.

In 2016, a local group founded the Bürgerverein Freising (BV) aiming at prevention of noise and air pollution with main focus on UFP. In contrast to bigger particles like $PM_{2.5}$ and PM_{10}, UFP cannot be measured by weight but in practice by counting only. To fund the special devices, the BV found donators, private individuals and the township of Freising, to acquire ultrafine particle counters as governmental support was denied. In 2018 the BV founded an UFP-measuring-network together with the nearby municipalities Wartenberg (together with Berglern and Fraunberg), Hallbergmoos and Neufahrn. Based on this network, for the first time the concentration of UFP was monitored around the Munich Airport [13]. The focus of the present study is to clarify the airport's share of UFP pollution. By this, we address corresponding information from other airports in Germany, although our studies are less detailed as compared to those of the Hessisches Landesamt für Naturschutz, Umwelt und Geologie (HLNUG) [20], the Hochschule of Düsseldorf [21], the Umweltbundesamt (UBA) [18] and others. Nevertheless, new and reliable data have been obtained which correspond to those published by the institutions mentioned above. This study not only indicates a direct correlation between air traffic intensity and UFP burden. It also indicates the possibility to discern air traffic UFP from road traffic and other sources. This work led to the development of *https://10nm.de/*, which provides a simulation of the potential UFP load at any participating airport based on wind conditions like wind direction and wind speed to finally offer a worldwide tool to visualize the burden of UFP and increase the awareness of the problem.

2 Methods

Two different devices were used in determining the number of ultrafine particles in ambient air: P Trak (CPC, condensation particle counter Co. TSI) and Discmini (based on electrical charging of aerosols; Co. Testo). To map the UFP concentrations, we applied both mobile and stationary measurements.

To carry out mobile measurements, a driving route was defined to reproducibly cover the perimeter of the airport in a distance of 1-17 km. The impactor (UFP-inlet) was fixed to the outside of the car. Both measuring devices record particle number once per second. In addition, the Discmini displays particle size (mode). Parallel to particle measurement the driving path was recorded using a conventional GPS device. After aligning times of measurement with the corresponding coordinates, a map of UFP pollution can be plotted. This type of measurements represents a snapshot of UFP burden at a particular time and location. Using particle size analyses in some instances the origin of UFP can be deduced. The larger the particles (> 60 nm), the greater the background load. The smaller the particles, the more likely the source is to come from road and air traffic. Aircraft engines emit the smallest particles [8; 18]. Thus, these mobile measurements not only provide information about particular areas but also provide UFP distribution patterns. In case of aircraft derived UFP the typical particle size is below 24 nm and the particle numbers are high (multiples of background which is considered to be 4,000-5,000 p/cm^3). Based on the travel route, the boundaries of the particle cloud in the downwind of the airport can thus be determined rather accurately.

Stationary measurements were performed repeatedly at different locations around the airport. The measuring period lasted several months. Care was taken to inspect the devices regularly including cleaning the impactor and collecting the data. Weather conditions were obtained from the station No. 1262 provided by the "Deutscher Wetterdienst", which among other parameters provides time resolved wind direction and speed. A specifically developed software allows to display the plume from the airport adapted from the official wind data (10*nm.de*, see 3.7 below).

3 Results and Discussion

3.1 Airports are significant sources and hotspots of ultrafine particulate matter

The Expert Hearing organized by the Environmental Committee of the Bavarian State Parliament in 2017 already denoted airports, particularly large airports, as hotspots of ultrafine particles. This description was closely confirmed by the 3rd Report of the HLNUG analyzing the Frankfurt International Airport UFP load [20].

Based on the data provided by the Deutsche Fluglärmdienst, [7], at from Munich Airport with more than 1,100 aircraft movements per day in 2019, more than 500,000 liters of kerosene are burned every day during the landing and take-off (LTO) cycles. This results in some 8 tons of air pollutants per day, including ultrafine particles. Together with gaseous products, UFP are the exclusive constituents in the exhaust of jet engines, where one gram of kerosene generates more than 10exp11 particles [19]. This results in an astronomic number of ultrafine particles – hundreds of trillions of UFP. During the LTO cycle, most of the particles are emitted at idle on the ground (the taxi in and taxi out time is calculated uniformly with 26 minutes). Therefore, a particularly large number of unburned hydrocarbons and gas molecules are generated which finally result in condensation products of UFP size. Several hundred different chemical compounds with toxic and carcinogenic properties [23] are the substrates that aggregate as ultrafine particles. Depending on the wind conditions, the jet exhaust is blown over the huge apron areas into the environment surrounding the airport where it contaminates the breathing air in the affected residential areas. In contrast to road vehicles, there are no technical options for aircraft engines to filter the pollutants out of the exhaust or to minimize them via a catalytic converter.

3.2 Decline of air traffic reduces noise and UFP, but not fine dust (PM_{10}, $PM_{2.5}$)

At Munich Airport, we compared the aircraft noise load, the concentrations of fine dust and the ultrafine particle pollution during the first two months in 2020, when flight frequencies were around 1,000 flights per day, and in April and May when the air traffic dropped to 68 and 58 flights per day, respectively (**Table 1**).

While the corresponding continuous sound pressure level remains rather high in January and February both at day and at night, the noise decreases in parallel with the number of flights after the lockdown. The same applies to the number of ultrafine particles. Interestingly, the fine dust concentrations remain high or even higher when the number of flights decreases. This coincides with the fact that kerosene combustion does not produce exhaust containing fine dust (PM_{10} or $PM_{2.5}$) but solely ultrafine particles [8].

Table 1 Aircraft noise (dB(A)), fine dust and ultrafine particle concentration prior to and after the lockdown

	Location	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	Reference
Ø Number of flights per day		996	1020	566	68	74	[10]
dB(A) $_{day}$	Pulling	61	61	56	36	n. d.	[7]
dB(A) $_{night}$	Pulling	51	51	48	39	n. d.	[7]
PM_{10} µg/m³	LHY 7	17	6	13	18	10	[10]
$PM_{2,5}$ µg/m³	LHY 7	13	4	7	11	8	[10]
UFP 1/cm³	MUC/Visitor center	n. d.	54,200	n. d.	7,100	n. d.	Figure 7

n. d. = not determined

3.3 Spreading of ultrafine particles depends on wind direction

Due to their extremely small mass, ultrafine particles sink very slowly, less than 1 mm/hour by gravity [5]. As a result, they tend to float in the air for a very long time and consequently their distribution depends entirely on the respective air movement. The first studies on the spreading of UFP came from the Los Angeles International Airport (LAX, USA). *Hudda* et al. [16] showed that the downwind plume of ultrafine particles stretches wedge shaped up to 16 kilometers into the direction of downtown Los Angeles (**Figure 1**).

Since in the study at Los Angeles airport the measurement routes are almost perpendicular to the wind direction, the area affected by the airport downwind can be located very accurately. This, however, is more difficult at many other airports due to the usually non-orthogonal road layout and the less constant wind conditions.

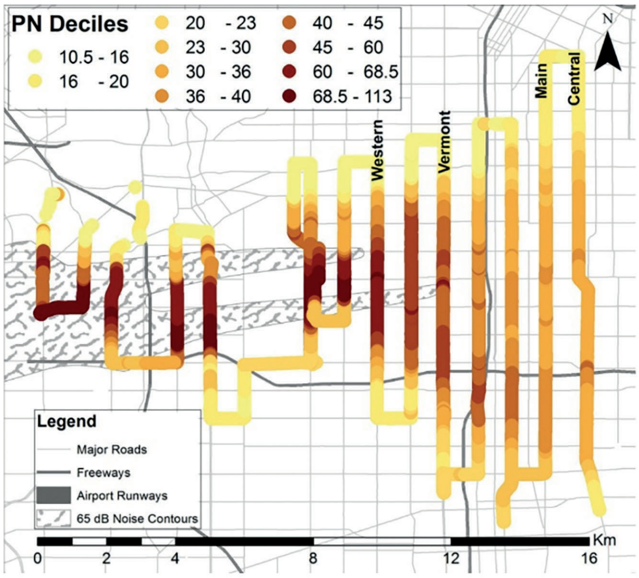

Figure 1 Spreading of the UFP cloud from Los Angeles International Airport (LAX) Wind is blowing from the airport (shaded area).
Source: Hudda et al. [16]

3.3.1 Mobile measurements around the Munich Airport

In analogy to the study of *Hudda* et al. [16] we carried out some 50 test runs around the Munich Airport measuring number and size of UFP. **Figure 2** shows the downwind plume moving westward from the Munich Airport by easterly wind.

UFP concentrations were recorded on the test run (yellow line in Figure 2) from the community of Achering towards Pulling. The graph on the left shows the increase of the UFP concentration when entering the downwind plume from 4,000 p/cm³ (background value) to some 55,000 p/cm³ and the decrease to almost background concentration when leaving the downwind plume. Approaching aircrafts contribute to this downwind plume

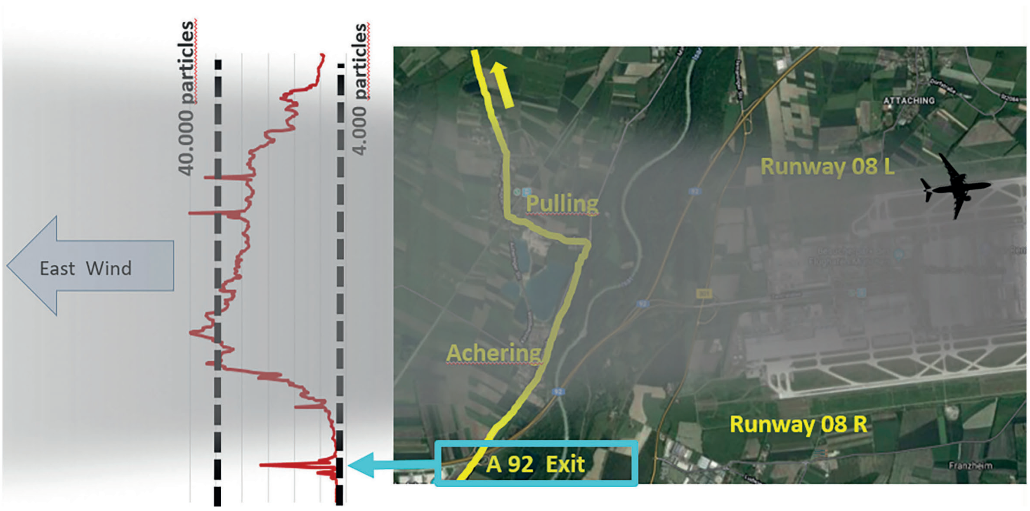

Figure 2 Spreading of the UFP cloud from Munich Airportand on the highway A 92. *Source: BV Freising*

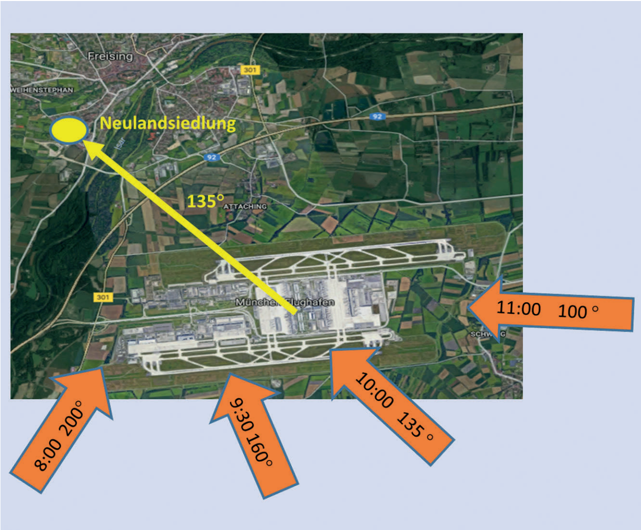

Figure 3a Stationary UFP measurement with changing winds at the site Neulandsiedlung. *Source: BV Freising*

by their wake vortices as they force the jet exhaust down to the ground. Also noteworthy are the UFP emissions from car traffic at the highway A 92 (see the peak lower left in figure 2) which show some 25,000 p/cm³, while UFP concentrations decline to background levels at about 200 meters distance from this highway after crossing the bridge. This indicates that the ultrafine particles from road traffic remain in a narrow corridor, quite different from the airport downwind with its large-scale distribution.

3.3.2 Stationary measurements

Stationary measurements can also vividly convey how the UFP load changes under the influence of wind. **Figure 3a** shows the site called Neulandsiedlung in Freising about six kilometers northwest of the airport center. The measuring point is exactly in the downwind of the airport when the wind blows from 135° southeast.

The *P* Trak device was used for this measurement detecting ultrafine particles from 201,000 nm. The wind (orange arrows)

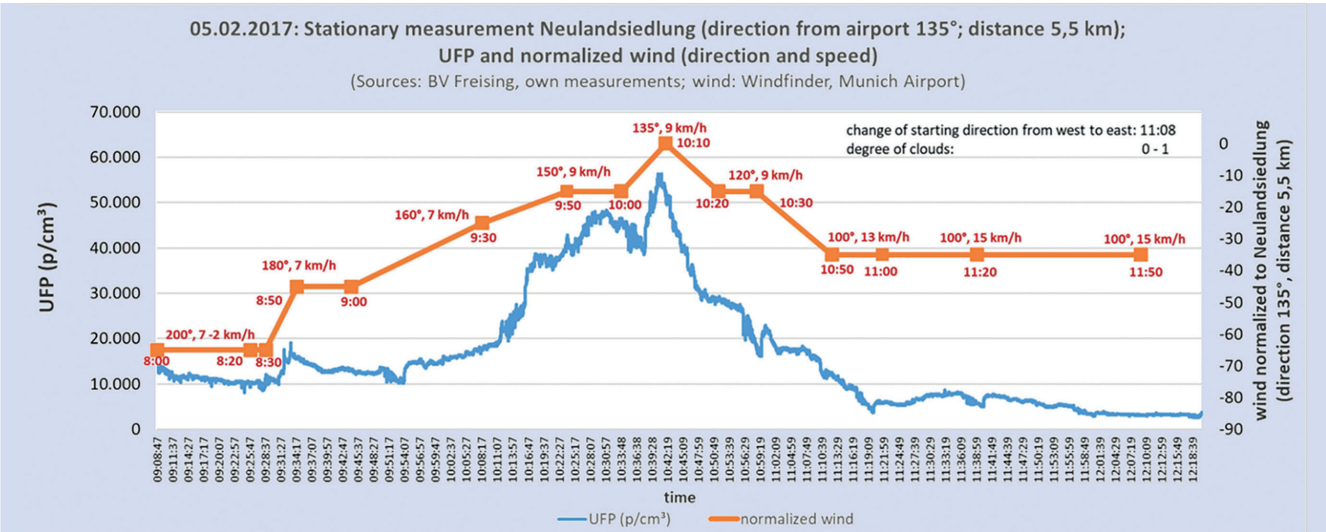

Figure 3b UFP concentrations as a function of the shifting wind at the site Neulandsiedlung. *Source: BV Freising*

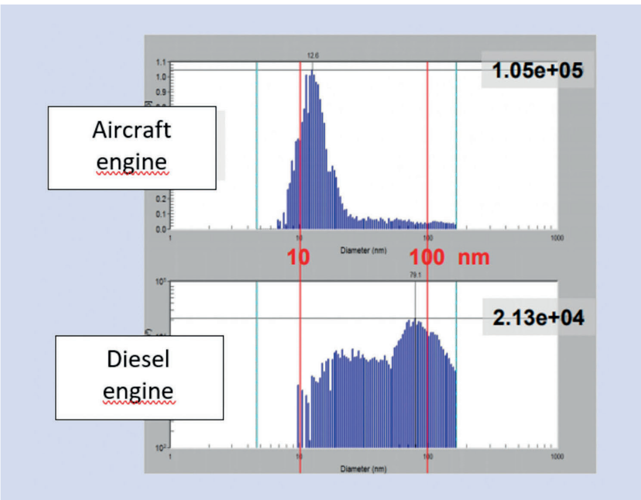

Figure 4 Size comparison of ultrafine particles from aircraft jet engine and diesel engine. *Source: [9]*

initially came from south-southwest (200°), turned to 135° within two hours, and later to 100° (easterly wind). Considering the wind speed and distance from the airport, the shape of the two curves in **Figure 3b** shows how the UFP concentration increases (blue line) when the wind blows more and more from 135°, reaching a maximum of 57,000 p/cm³ (orange line). When the wind blows from 100° (east), the UFP emissions from the airport completely miss the site Neulandsiedlung. As a result, the UFP burden drops below 4,000 p/cm³.

3.4 Very small particles indicate aircraft jet origin

The higher the pressure and temperature, the smaller the particles produced during combustion. In contrast to other combustion engines, aircraft engines therefore emit only gases and ultrafine particles. **Figure 4** shows a comparison of particle sizes from jet engines (kerosene) and car engines (diesel). While the modal value of UFP from an aircraft engine is 13 nm, it is almost 80 nm in diesel combustion [12]. The distributions overlap considerably,

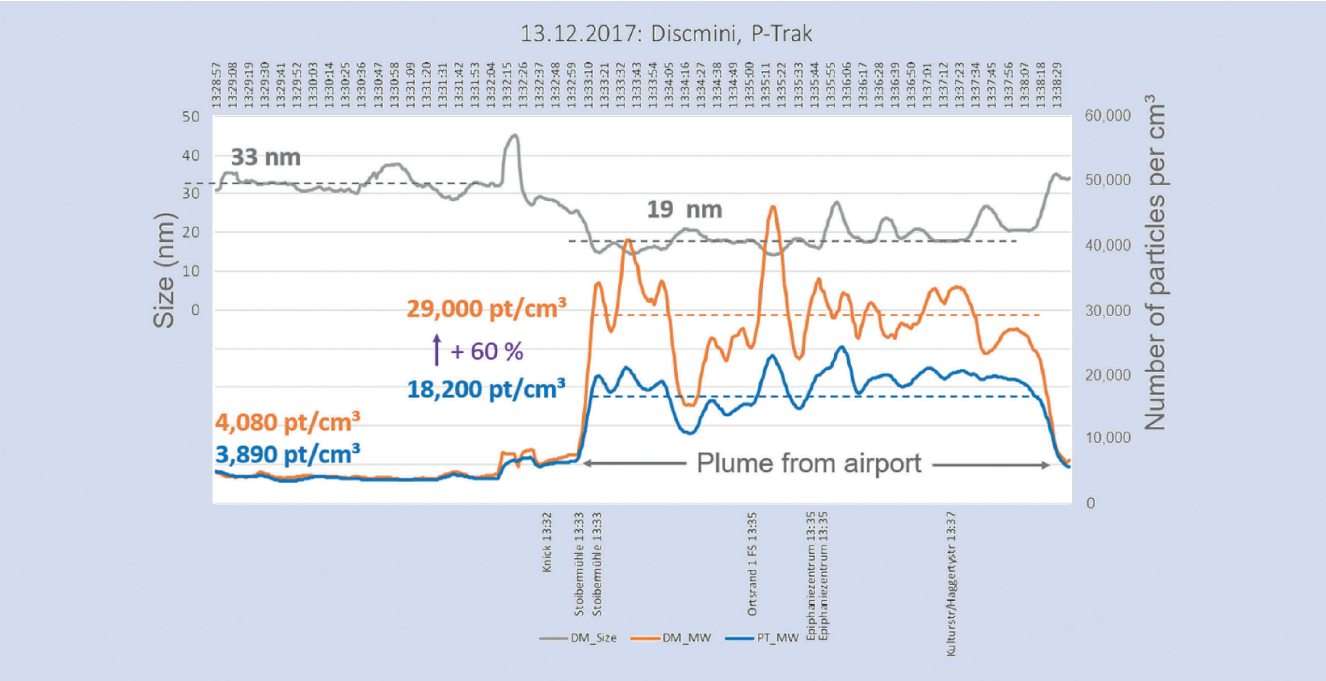

Figure 5 Progress of particle concentration and size in the downwind of the Munich Airport. Gray: Particle size in nm; orange: UFP concentration as determined using the Discmini (1/cm³); blue: UFP concentration using the P Trak (1/cm³). *Source: BV Freising*

so that a clear distinction between the two origins is practically impossible. In addition, UFP increases in size over time and therefore in distance from the source due to agglomeration [22], also known as aging.

Despite these uncertainties, the source of ultrafine dust becomes discernible. A mobile measurement run with Discmini and P Trak showed that the particle size changes when the UFP cloud from the airport is reached (shaded area in **Figure 5**). In this case, the downwind plume extended over a distance of about 5 km deducible from time (5 min) and driving speed (60 km/h).

The background levels of ultrafine particles out of the downwind plume were some 4,000 p/cm³ as measured with P Trak and Discmini. When entering the plume, the difference between the values becomes greater, due to the different measuring ranges of the devices, displayed by Discmini (orange) and P-Trak (blue): the Discmini measures particles bigger than 10 nm and the P Trak bigger than 20 nm. The particle size at background levels as determined by Discmini was 33 nm. The route used for these measurements headed at about 5 km north of the airport into the downwind plume, where the UFP concentrations increased to 18,200 and 29,000 p/cm³, respectively. At the same time, modal value of the particle size dropped to 19 nm. This coincidence of increasing UFP concentration and decreasing UFP size as soon as the downwind plume of the air traffic was reached (in this case wind from the south), is a clear indication of a large contribution of UFP load from aircraft engine exhaust.

In another mobile test run (April 2018) in the downwind of the airport even at a distance of 12 kilometers, the particle diameter was reduced to 28–31 nm as compared to 50-70 nm outside the downwind plume (data not shown). This size distribution also clearly indicates the origin of the particles from aircraft engines, as other emitters could be excluded.

Figure 6 Discmini measurement close to the apron of the Munich Airport-shows a UFP concentration (≤10 nm) of 1.35 Mio. p/cm³. *Source: BV Freising*

Measurements at the Munich Airport center or at the fence of the apron provide a tangible impression of the magnitude of the amount of burned kerosene. At these locations, the concentrations can reach levels above 1.3 million p/cm³ (acrid odor), whereby the Discmini measures the particle size from 10 nm. Since this is the lower limit of the of the measurement range of the Discmini, all particles smaller than 10 nm are not detected (see also Figure 4). Thus, an even higher concentration of UFP has to be considered. **Figure 6** shows an example result from the eastern apron with 1,350,000 particles/cm³ (diameter 10 nm).

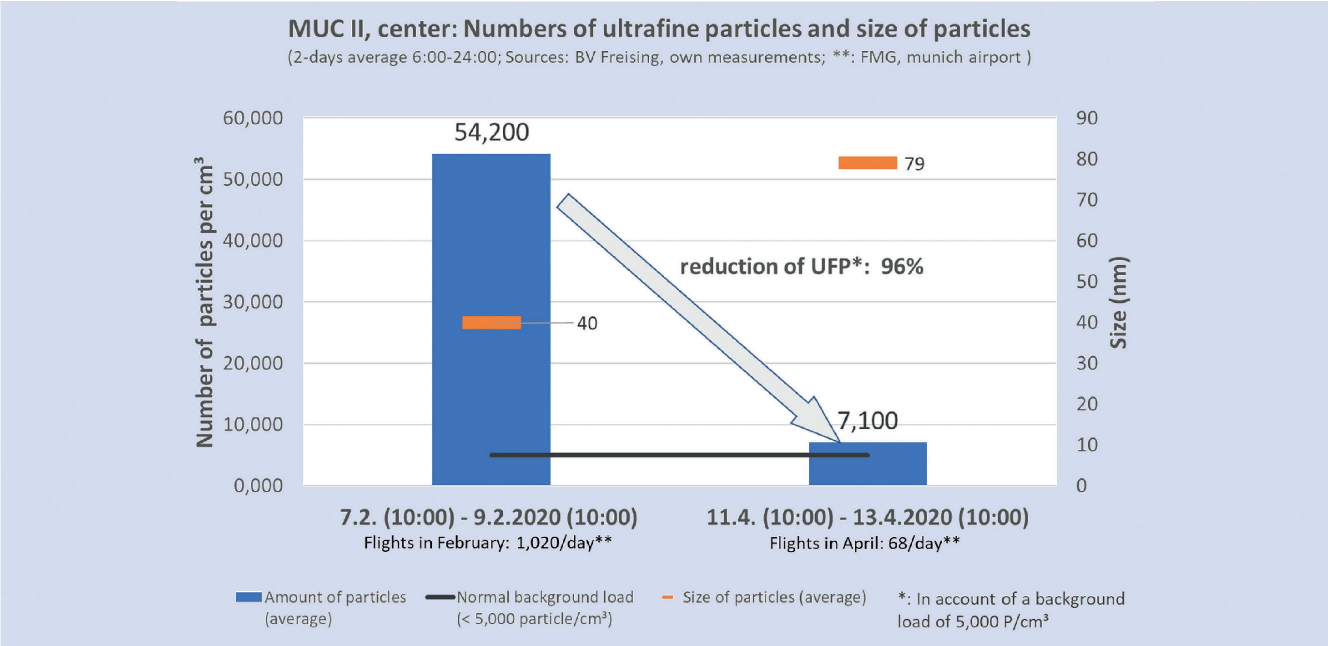

Figure 7 Decrease in the UFP load after Corona lockdown (location: Airport Hopser) *Source: BV Freising; Source**: FMG, Munich Airport*

3.5 Decrease in UFP levels at Munich Airport due to Corona restrictions

Prior to the outbreak of the Covid-19 pandemic, a stationary measurement in February 2020 was carried out at the airport near the visitor center and the daycare center called Airport Hopser over two days. **Figure** 7 shows the mean concentration of ultrafine particles ($54{,}200\ p/cm^3$). The measurement was repeated during the lockdown period on April 11–13, 2020. Here the mean value was $7{,}100\ p/cm^3$. The modal values of particle size also behaved as expected: In February when UFP concentrations were high, the modal value was 40 nm (heavy air traffic), and 79 nm when there were few flights. In the latter case the fraction of UFP from other sources predominated.

3.5.1 Increase in UFP levels with the number of flights at Munich Airport

During June to August 2020, when lockdown conditions eased, stationary measurements were carried out at the airport with the Discmini. During that time the number of aircraft movements increased slightly. **Figures 8a-c** plot the hourly means of UFP concentrations by months, days and hours. The correlation between the number of flight movements and the UFP load can clearly be recognized as described below.

3.6 Overview of the regional UFP pollution

The results from many measurement runs show a consistent picture: Whenever the wind comes from the airport, it carries the UFP enriched air in a wedge-shaped plume up to more than 17 km long. Mobile measurements are snapshots. Nevertheless, if the wind is blowing from the airport, the UFP concentrations were always elevated while in parallel the particle size became smaller. The UFP concentrations at the measurement sites directly depend on the weather conditions (wind direction, wind strength, inversion etc.) and how long the respective site is exposed – and of course on the number of flights at the airport. **Figure 9** provides an overview of ultrafine particulate burden measured at various sites exposed to the airport downwind.

3.7 Web page: *10nm.de*

Our results fostered the development of *https://10nm.de/*, which intends to provide a simulation of the potential UFP load at any airport based on wind conditions like wind direction and wind speed.

According to all the findings obtained in the USA, Europe, especially in Frankfurt and Munich, ultrafine particulate matter is the most significant feature at airports in terms of air pollution. Pollution depends on the amount of kerosene burned during LTO cycles and the prevailing wind conditions. The air passing over the airport surface picks up the ultrafine particles and transports them downwind in a wedge shape to the surroundings (see Figures 1 and 2). The higher the wind speed is, the narrower the downwind wedge. The slower the air movement, the wider the downwind cloud spreads.

Taking wind conditions into account it is therefore possible to simulate and dynamically display the potential ultrafine particle input into the airport‘s surrounding environment. The UFP website *https://10nm.de* uses wind data available on the Internet to visualize the speading of ultrafine particles originating from Munich Airport. The current website has been expanded to include several airports. The website is self-explanatory. When the desired airport is entered, the page shows whether a certain location is downwind and, if so, since when.

3.8 Ultrafine particulate matter – the most harmful fraction of fine dust particles for health

By definition, all particles with a diameter smaller than 100 nm belong to the fraction of UFP, the smallest solid (or liquid)

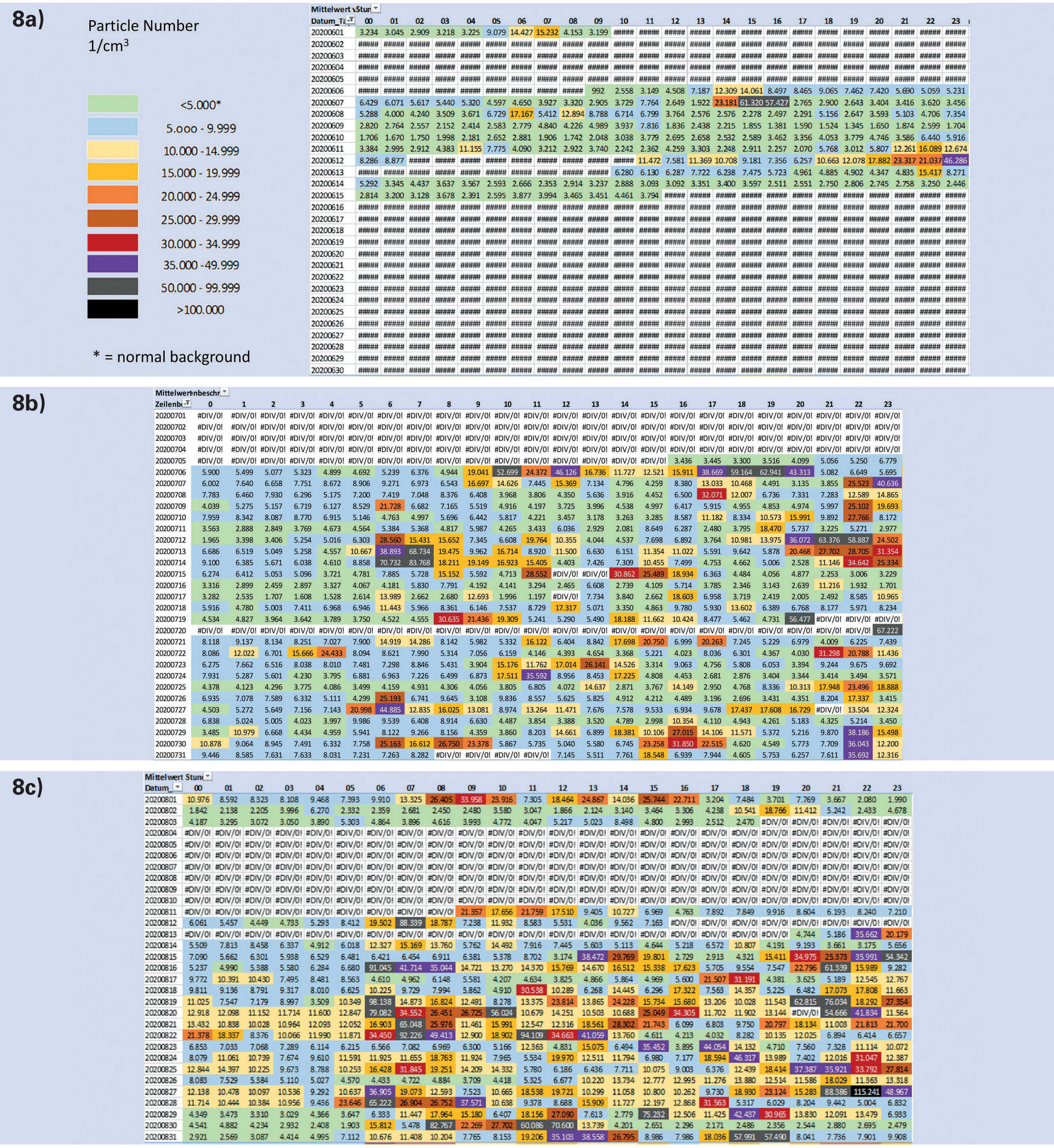

Figure 8 Location Visitor Center – Increase of ultrafine dust mean values from June to August 2020. Hourly UFP concentrations: **8a** = June, 160 flights/day; **8b** = July, 328 flights/day; **8c** = August, 403 flights/day; Days are depicted "vertically"; Hours are depicted "horizontally"; Legend: "Light green" indicates UFP concentrations < 5,000 p/cm³; "Blue" indicates < 10,000 p/cm³. The darker the red colors, the higher the UFP concentration (up to 100,000 p/cm³). The World Health Organization (WHO) classifies hourly averages above 20,000 p/cm³ as high. This applies to the colors red, dark red, violet and black.
Source: BV Freising

particles in the air. During the combustion of kerosene containing additives, UFP are formed by unburned hydrocarbons and gaseous combustion products many of which having toxic and carcinogenic properties. Hundreds of different chemical compounds are detectable in the exhaust stream from jet engines [1; 23] and they interact with the carbon particles and other molecules. High pressure and temperature in modern jet engines force UFP to rarely be bigger than 100 nm; mostly their size is around 13 nm in diameter when leaving the jet [8]

Due to their small size, ultrafine particles can not only penetrate deeply into the lungs and enter the bloodstream but also enter living cells in our bodies by a process very similar to the uptake of the modern RNA vaccines against Covid SARS 2. There, however, based on their chemical nature, UFP elicit toxic

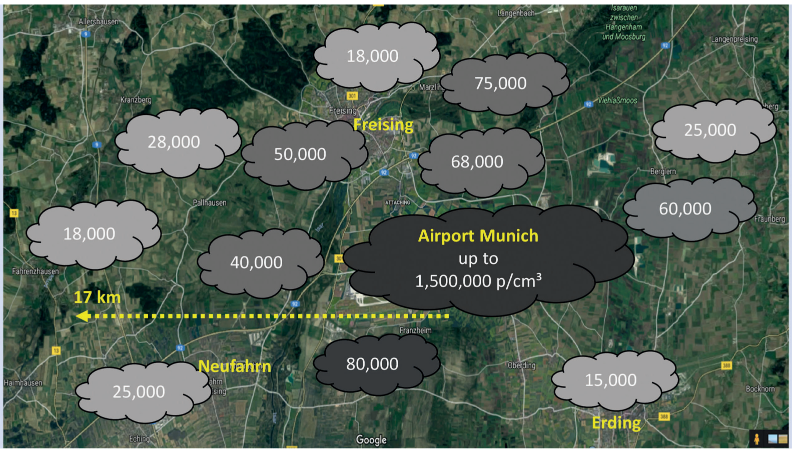

Figure 9 Highest UFP concentrations at the Munich Airport Center. Still high concentrations at distant sites (up to 17 km) when wind is blowing from the airport. Normal background load: < 5,000 particles/cm³. Numerical values: particles/cm³. Mobile measurements in 2017-2019. *Source: BV Freising*

reactions and are able to disrupt cellular processes, trigger oxidative stress, damage cell structures and functional molecules [11]. The danger and extend of these damages correlate with number and time of UFP exposure. All publications on such toxicological experiments indeed show, that combustion derived UFP enter body cells, disrupt and damage biochemical processes, which can be a prerequisite or immediate onset of various diseases [17]. *Hoffmann* [15] concluded from epidemiological studies that there is very strong evidence for acute effects on lung disorders (lung function and inflammation) and cardiovascular effects (blood pressure, heart attacks, etc.).

Nevertheless, it remains difficult to accurately quantify and define a UFP concentration that identifies a threshold for health risk to populations or individuals because of the high number of factors involved. Epidemiological studies are still necessary to find the relevant variables crucial to the health risks of UFP. Although some studies still contain inconclusive results, none could show that ultrafine particles are not harmful to health.

The health risk imposed by ultrafine particles is repeatedly addressed by various institutions, such as the World Health Organization (WHO), the German Federal Environmental Agency (UBA), the Leopoldina (National Academy of Sciences) and others. Due to the difficulties mentioned above still no limit value could be issued for UFP. Instead, these organizations call for minimizing UFP emissions as much as possible. As evidence of adverse health effects is accumulating, efforts to minimize UFP burden should become a political imperative.

Measures to mitigate ultrafine particles at airports would be available and quickly implementable, as the Secretary of Environment of the Federal State of Hesse in Germany, *Hinz* [14] is quoted in the press release of the 3rd report of the Hessian State Agency for Nature Conservation, Environment and Geology (HLNUG). The author confirmed that the decline of flight numbers following the Covid-19 restrictions has led to a significant decrease in exposure to ultrafine particulate matter: „This involuntary field test has confirmed the previous findings of the HLNUG on the influence of flight operations on the concentration of ultrafine particles." She concluded: „One fast-acting way to reduce pollutant emissions is, for example, to reduce the sulfur content of kerosene. To achieve this, we need clear Europe-wide targets. In addition, aircraft combustion processes on the airport site must be avoided as much as possible. To achieve this, greater use of electric vehicles is essential, for example the taxiing of aircrafts".

4 Conclusions

The data clearly demonstrate the extent to which the regional air quality depends on the flight frequencies. For instance, a decline of air traffic by 93% reduces UFP-concentration by the same magnitude. The measured particle sizes indicate their origin from aircraft engines.

Our mobile and stationary measurements prove a considerable regional UFP pollution around Munich Airport. The intensity of the spreading of ultrafine particles clearly depends on the wind direction. UFP pollution is the most harmful fraction of fine dust particles for health. Due to their small size, ultrafine particles can not only penetrate deeply into the lungs and enter the bloodstream but also enter living cells all over the body.

Any provision to reduce the intensity of the air traffic should generate corresponding improvements of the air quality. However, the current traffic concepts and the actual dumping prize constellations in favor of air traffic as compared to rail traffic will not result in a substantial decline of flight frequencies in the near future. In addition, new propulsion concepts (synthetic fuels, hydrogen, electric drives) are either not yet available or economically uncompetitive. Therefore, additional precautions to improve air quality are urgently needed.

An effective way to reduce emissions originating from kerosene combustion during the LTO-cycle, is the use of electrified aircraft tugs towing the aircrafts from the gate to the runway and after the landing back to the gate. Normally, aircraft engines run at low temperatures at idle on the ground, emitting the largest amounts of unburned hydrocarbons and harmful gas molecules. In order to avoid such pollution, the semi-robotic TaxiBot system of the Israel Aerospace Industries (IAI) was tested in 2014 e.g. [2] and licensed 2017 for the series of Boing 737 and Airbus A-320 [3; 4]. The TaxiBot system stops the use of aircraft engines during taxiing, significantly reduces kerosene consumption and corresponding pollution and avoids noise. The system is pilot controlled using the regular pilot control tools and has an 800 hp hybrid-electric engine. It can be used with or without the aircraft's APU (Auxiliary Power Unit). The TaxiBot system is operating since 2018 in India at the New Delhi International Airport and since 2020 in the Netherlands at Schiphol Airport in Amsterdam.

TaxiBot as a sufficiently proven system for an efficient reduction of UFP pollution could be one of the available solutions for the UFP problem and should be taken into account by the officials of the Munich Airport and any other international or national airport.

ACKNOWLEDGEMENTS

We greatly appreciate the help of Bürgerverein Freising (BV) and Network (NW) for UFP monitoring: Dr. *Christopher Aichinger* (BV), *Marita Anzinger* (Network NW), Dr. *Josef Cyrys* (NW), *Tobias Eschenbacher* (Mayor, Freising), *Ute Freiwald* (NW), *Markus Geier* (BV), *Erwin Grießer* (NW), *Gabi Hartinger* (BV), *Michael Hauner* (BV), *Jochen Hellmich* (BV), *Hermann Hofer* (NW), *Konrad Huber* (NW), *Brigitte Huppertz* (NW), *Andreas Kern* (BV), *Stefan Kiesl* (NW), *Georg Kramer* (NW), *Christoph Kröhlinger* (NW), *H. Langenbacher* (Fa. Testo), *Silvana Mayrthaler* (NW), *Christian Oberhofer* (NW), *Christel Orthen-Schmuker* (BV), *Helmut Petz* (District Administrator, Freising), Parish association Freising, *Florian Pflügler* (BV), *Manfred Pointner* (Local citizen organization to protect against the burden of Munich Airport), *Harald Printz* (BV), *Manfred Ranft* (NW), *Leo Rauschecker* (NW), *Karl-Heinz Reingruber* (NW), *Ferdinand Reuss* (NW), *Michael Rottenkolber* (NW), *Peter Schickinger* (NW), *Michael Url* (NW), *Robert Wäger* (NW), Dr. *Katrin Wolf* (NW).

We express sincere thanks for financial and technical support to *Thomas Bauer*, the Township of Freising, the communities Wartenberg/Berglern/Fraunberg, Hallbergmoos and Neufahrn.

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