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Air pollution and the COVID-19 epidemic

Six aspects discussed by the Federal Commission for Air Hygiene

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The Federal Commission for Air Hygiene (FCAH) is an extra-parliamentary committee of experts in the field of air pollution control, appointed by the Federal Council. It advises the Federal Department of the Environment, Transport, Energy and Communications (DETEC) and the Federal Office for the Environment (FOEN) on scientific and methodological questions relating to air pollution control and on the assessment of the effects of air pollution on human health and the natural world. As far as its function is concerned, the FCAH is an independent and interdisciplinary administrative commission, which is also able to call upon external experts from different fields to advise on individual questions.

After its meeting in May 2020, the FCAH unanimously adopted these six aspects by correspondence (ending on 2 June 2020).

Members of the Commission

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Summary

The role of air pollution in the spread of SARS-CoV-2 and the development of the COVID-19 pandemic has been the subject of public debate for several weeks. In this report, the FCAH discusses six aspects relating to air pollution and the COVID-19 epidemic.

Virus spread: A link between the daily fluctuation of particulate matter pollution and the incidence of SARS-CoV-2 infections has not been confirmed. The COVID-19 epidemic does not constitute grounds for emergency air-hygiene measures for a short-term reduction in particulate matter pollution during the epidemic.

Health status of the population: Thanks to Switzerland's successful air pollution control policies, the proportion of people in the COVID-19 risk groups is smaller than if air pollution had remained at the levels seen in the 1980s or 1990s.

Individual susceptibility: High pollution levels could weaken defence against SARS-CoV-2 infection by affecting the immune system. A link with high levels of air pollution has been scientifically proven for certain diseases, but currently not for COVID-19. In Switzerland, air pollution is likely to play a minor role compared with the driving factors behind the pandemic.

Progression of COVID-19: It can be postulated as a plausible hypothesis that air pollution has an influence on the progression and thus the severity of COVID-19. However, there is currently no direct evidence for this hypothesis with respect to COVID-19. As pollution levels in Switzerland are low, this aspect should not be a significant factor.

Long-term effects of COVID-19: Nothing is yet known about the impact of air pollution on the progression of COVID-19's long-term effects. However, interactions are conceivable.

Pollution levels during the lockdown: The lockdown affected many pollutant sources and in particular led to a reduction in traffic. The resulting drop in primary pollutant emissions is reflected in exposure levels, mainly those recorded at monitoring locations close to pollutant sources. A precise quantification of the pollutant changes and their impact on health will require data analyses over extended periods, taking into account all other factors (e.g. weather). Simply comparing measurement data before and during the lockdown is not sufficient.

During the COVID-19 crisis, Switzerland has greatly benefited from its successful air pollution control policies over the past 35 years. A permanent reduction in air pollutants is vital to achieve a sustained improvement in air quality and thus public health. Emissions of particulate matter, nitrogen oxides, volatile organic compounds and ammonia must be further reduced by consistently promoting state-of-the-art technology in motor vehicles, agricultural and industrial installations, heating systems and other emission sources, both in Switzerland and internationally, and by complying with the requirements of the Environmental Protection Act and the Ordinance on Air Pollution Control. Measures must continue to be enforced after the coronavirus pandemic and the improvement in air quality must be verified by standardised measurements. Internationally, Switzerland should work to ensure that the science-based air quality guidelines proposed by the World Health Organization (WHO) for the protection of health are adhered to globally.

Air pollution and the COVID-19 epidemic. Six aspects discussed by the FCAH

The role of air pollution in the spread of SARS-CoV-2 and the development of the COVID-19 pandemic has been the subject of public debate for several weeks. The fact that Chinese cities are among the most polluted cities in the world and that Lombardy – one of the regions hardest hit by COVID-19 – has for years been one of Europe's most polluted regions, has tempted some people to draw a causal link and suggest that the major outbreaks seen in Wuhan and northern Italy can be explained by the high levels of air pollution. In the following report, six theoretically important interfaces between the pollutants regulated in the Ordinance on Air Pollution Control (OAPC) and the COVID-19 epidemic are discussed. For each aspect, the theoretical context is summarised, and brief consideration is then given to the current knowledge and unanswered questions. The aspects are dealt with in the order of epidemiological chronology (spread of SARS-CoV-2 → health status of the affected population → individual susceptibility → progression of COVID-19 disease → long-term effects of COVID-19). Finally (in Aspect 6), we discuss the impact of the lockdown on air pollution levels.

The report presents the situation as currently perceived by the FCAH (5 June 2020). The topic is work in progress and future knowledge may supplement or change the perspective set out here. Comments on the aspects discussed are always welcome. References to the literature have not been included but can be provided upon request.

Aspect 1: Role of particulate matter in the spread of SARS-CoV-2

Droplet infection is central to the spread of the virus. Droplets are usually heavy enough to fall to the ground within a narrow radius (up to 2 metres). However, SARS-CoV-2 viruses can also be spread via microdroplets (up to 5 micrometres in diameter). Such aerosols can remain in the air for much longer and can therefore also travel further. This mode of transmission could increase the transmission risk indoors. Consequently, 'no-regret' preventive strategies are called for, such as the wearing of masks in heavily frequented indoor spaces and well-maintained ventilation systems equipped with filters. That said, little experimental evidence is yet available and the exact epidemiological quantification of the relevance of these transmission routes for SARS-CoV-2 has yet to be determined.

However, the main focus of Aspect 1 is not the general question of SARS-CoV-2 spread but rather the contribution of air pollution – especially particulate matter (PM) – to spreading the virus. It has been suggested, particularly in the Italian media, that higher levels of PM contributed to the rapid transmission of the virus. According to this hypothesis, the exponential COVID-19 curve seen in northern Italy would have been flatter if PM concentrations in late February / early March had been lower. PM remains in the air for much longer than droplets and is distributed over much greater distances. The theory therefore implies that PM serves as a virus carrier, increasing the length of time the virus remains in the air and its spread. Based on this theory, the following example could be postulated: assuming there are 20,000 viruses per cm^3 released into the air by the cough of an infected person, the number of viruses combining with particulates would be greater in more polluted ambient air containing (say) 40,000 particulates per cm^3 than in air containing only 10,000 particulates per cm^3. The theory presupposes that a) the viruses coughed out in droplets combine with the particulates, b) the degree of combination depends on the PM concentration, c) the viruses on these carriers remain infectious and d) the length of time that the viruses remain in the air and their infectivity are prolonged as a result. Only under these conditions would the concentration and residence time of SARS-CoV-2 in the ambient air around infected individuals depend in part on the PM pollution in the ambient air. Assuming that all other epidemiologically relevant factors remain constant, this would imply that in epidemic areas more people are infected on days with higher PM pollution than on days with lower pollution levels.

Position 1 and unanswered questions:

There is no evidence for the postulate that PM concentration additionally influences virus spread over long distances, and there are many unanswered questions about the physical and biological plausibility of this theory. While an Italian study succeeded in demonstrating the presence of SARS-CoV-2 fragments (RNA) on PM, the relevance with respect to the transmission and/or infectivity of these fragments is questionable and has not been proven experimentally. It is not known whether the loading of PM with such fragments depends on the PM concentration in the ambient air.

The postulated link between daily PM pollution levels and the incidence of COVID-19 cases would need to be investigated using methodologically sound multivariate analyses of time series of all factors relevant to the spread of the epidemic. The most significant outcome for this hypothesis would be the occurrence of new cases as a function of the daily fluctuations in PM pollution (severity, progression and mortality are dealt with in subsequent aspects). As is well known, counting new cases is fraught with difficulty due to the many asymptomatic or mild cases, as well as incomplete testing and variations in reporting systems worldwide. Moreover, the testing required for accurate counting depends on a number of external factors, which not only vary from region to region but are also subject to organisational changes over the course of the epidemic (e.g. availability and distribution of the tests, testing strategies, etc.). Comprehensive and high-quality information about the profile of cases and of the behavioural rules imposed (and adopted) in the respective region would also need to be available for the analyses. In addition, weather parameters would have to be factored into the evaluation, since pollution levels and possibly also SARS-CoV-2 distribution are temperature-dependent.

Since COVID-19 spreads exponentially until measures are imposed, and since the most important measure (i.e. physical distancing in particular) is extremely effective at interrupting this 'natural progression', the influence of such measures (and compliance with them) prevails over all other theoretically possible influencing factors such as PM pollution. Consequently, the influence of the latter could only be statistically proven if comprehensive data series from different regions were examined and compared over extended periods before and after the pandemic.

None of the studies published to date meet these scientific requirements. Neither correlations between possible increases in pollutants in the early phase of the epidemic nor the correlation between a lockdown-related decrease in pollutants and a parallel drop in the number of COVID-19 cases can be used to draw causal conclusions. Compared with the epidemiologically most important factors, in particular physical distancing, the postulated link (if it can ever be proven) is likely to be quantitatively irrelevant. The sharp downturn in the epidemic observed worldwide after the introduction of physical distancing rules also suggests that PM concentrations do not play a role in transmission of the virus, since PM remains in the air for days to weeks and could be distributed over many kilometres in a horizontal air flow.

Furthermore, the postulated link would be completely irrelevant for epidemic management since PM pollution can barely be influenced in the short term by emergency air-hygiene measures (see also Aspect 6). The goal of good air quality can only be achieved by sustained, comprehensive air pollution control measures, such as those that have been successfully prioritised and implemented under Swiss air pollution control policies for the past 30 years and more.

Conclusion 1:

A link between the daily fluctuation of PM pollution and the incidence of SARS-CoV-2 infections has not been confirmed and does not currently seem plausible. The COVID-19 epidemic does not constitute grounds for calling for emergency measures for a short-term reduction in PM pollution during epidemic waves.

Aspect 2: Air pollution and number of people in 'risk groups'

In Switzerland as elsewhere, experience during the first months of COVID-19 confirms that people with pre-existing chronic diseases are heavily over-represented among COVID-19 patients. These risk groups have a higher likelihood of severe illness and death. The main risk groups currently defined are people with pre-existing cardiovascular diseases, respiratory diseases, cancer and diabetes. Being overweight is also defined as a COVID-19 risk factor. This observation would suggest that the epidemic is less severe in regions with a lower prevalence of these risk factors than in regions where the proportion of these patient groups is higher. The question of the role played by air pollution in the development of these 'risk diseases' comes to the fore here.

Position 2 and unanswered questions:

Research over the past 30 years – in which Swiss research teams have played a leading part – shows a causal link between long-term exposure to air pollutants such as PM, nitrogen oxides and other components of the complex air pollution mix and the occurrence of the aforementioned risk diseases. In particular, air pollution contributes to the most important pathology of cardiovascular diseases, namely atherosclerosis, and causes the development of asthma in children and chronic lung diseases in adults. In addition, PM is classified as a carcinogenic substance, with the causation of lung cancer being best documented. The link between air pollution and the development of diabetes has been proven both experimentally and epidemiologically (including in the Swiss SAPALDIA study). Moreover, there are plausible theories supporting the hypothesis that air pollution contributes to the development of overweight.

It can therefore be assumed that in regions with high levels of pollution and regions with a high proportion of smokers or overweight people, the COVID-19 risk group is larger – and consequently a higher COVID-19 death rate is to be expected – than in regions with a less polluted environment and healthier living conditions. An analysis by researchers from Harvard University quantified the link between the home outdoor residential long-term PM pollution and the proportion of COVID-19 deaths. While the postulated link was established, the analysis was criticised in the peer review and corrected. Results from international studies are needed before this link can be quantified.

For regions such as northern Italy, which have accorded less priority to air pollution control than Switzerland, and especially for heavily polluted cities in Asia, it must be assumed that the proportion of COVID-19 risk groups is greater than in regions that have consistently and successfully worked towards meeting the WHO's air quality guideline values in recent years. On the other hand, better air quality has increased life expectancy and thus the proportion of the elderly in the population in less polluted regions. While the elderly are also a COVID-19 risk group, diseases with increased risk for severe COVID-19 have a much greater impact on the severity of COVID-19 progression than age *per se*. To date, there are no scientific calculations on the impacts of delayed implementation of environmental policy.

Conclusion 2: Current knowledge about the role of air pollution in the development of chronic diseases leads to the conclusion that in countries like Switzerland, with very successful air pollution control policies and consequently low air pollution levels, there are now fewer people in the COVID-19 risk group than there would have been if air pollution had remained at the levels seen in the 1980s or 1990s. This benefit of air pollution control has not yet been quantified for the coronavirus epidemic.

Aspect 3: Role of air pollution in susceptibility to SARS-CoV-2

If 1,000 people of the same age and belonging to the same risk group were exposed to the same dose of SARS-CoV-2 viruses in an experiment, they would not all experience the same COVID-19 progression. Individual susceptibility factors always play a role. These range from genetic, molecular and immunological factors to socio-demographic conditions, lifestyle and diet. Acute exposure to air pollutants – such as PM – results in local and systemic inflammatory reactions. The activation of these inflammatory cascades plays a role in the defence against and progression of infections. For example, a short-term increase in pollutant concentrations is associated with an acute increase in hospital admissions for pneumonia. This link is particularly well documented in children and in patients with chronic lung disease (COPD). Controlled intervention studies involving children have also shown that a vitamin-rich diet is a protective factor against the negative effects of summer smog (ozone), even in children whose genetic profile suggests they have a weakened defence against oxidative damage.

Such knowledge leads to the theory that increased pollution levels weaken defence against SARS-CoV-2 viruses. This would mean that days with increased pollution levels should be followed by days with a higher number of new infections, which would then drop again as pollution levels decrease.

Position 3 and unanswered questions:

The current knowledge suggests that air pollution weakens the human body's defence against infectious diseases. To date, no research has been carried out into whether and to what extent this also applies to susceptibility to SARS-CoV-2 viruses. Conducting methodologically sound research into this susceptibility during the acute phase of the pandemic is subject to the same challenges as set out in Aspect 1. Assuming that these viruses could trigger repeated (but hopefully smaller) epidemics worldwide in the future, the hypothesis of the link with pollution levels could be examined and quantified. If the link were of a similar magnitude to that between pollution levels and non-specific lung diseases, the contribution of pollutants to the spread of the epidemic would certainly not be in the exponential range. For example, a 10 μg/m^3 increase in PM pollution increases hospital admissions for respiratory diseases by a small percentage. Fluctuations of 10–20 μg/m^3 in the daily mean values can occur in Switzerland in the winter months. By way of comparison: in the early phase of the COVID-19 pandemic, the daily increases in the number of COVID-19 cases before the implementation of voluntary or mandatory measures were in the range of 30–50%, with the number of cases doubling within a few days. In case of an empirical confirmation of the above link, this could be included in the next calculation of the health benefits of Swiss air pollution control policies.

Conclusion 3: On days with higher pollution levels, people infected with the SARS-CoV-2 virus could be more susceptible to a clinically relevant progression of COVID-19. While the link has not yet been empirically proven for COVID-19, a conclusion by analogy, based on current knowledge of the effects of air pollution, would be plausible. If the conclusion by analogy also applies quantitatively, the implication would be that the contribution of air pollution plays only a minor role compared with the driving factors behind the pandemic.

Aspect 4: Air pollution and acute progression of COVID-19

Once infection by SARS-CoV-2 has taken place, the clinical progression of COVID-19 becomes the central issue for patients and the healthcare system. Many infections are known to have an asymptomatic or mild progression. Acute aggravation, severe illness, hospitalisation and the need for intensive care treatment or ventilation are rare, but are of central importance when it comes to the impacts, costs and management of the epidemic. As noted above, the aforementioned risk groups are heavily over-represented among cases of severe illness and death. The question arises whether, after infection (Aspect 3), the progression of COVID-19 disease is negatively affected by air pollution.

Position 4 and unanswered questions:

The main anthropogenic air pollutants have strongly oxidative properties. Exposure to these pollutants triggers pulmonary and systemic, acute inflammatory reactions. Adverse changes in blood clotting patterns and heart rate variability have also been shown experimentally and epidemiologically to be an acute consequence of such exposure. The aforementioned increase in hospital admissions for pneumonias also suggests that the pollutants affect the progression of these conditions.

Severe cases require hospitalisation and pharmaceutical interventions. The question as to whether the pollutants affect the progress of therapy is therefore of interest. Few epidemiological studies in recent years have addressed these clinical questions. Studies of large patient cohorts in California found that therapy for lung cancer patients was more successful and that tuberculosis patients responded better to tuberculostatic therapy the lower the ambient air pollution levels at their home address. In both patient cohorts, this benefit was also demonstrated by an increased survival rate. Disease progression in cardiovascular patients admitted to the intensive care unit of a Chinese hospital due to other (non-cardiovascular) conditions was worse the higher the pollution levels were on the days prior to their admission. In a Canadian cohort of heart attack patients, long-term progression was also negatively affected by air pollution. To date, none of the aforementioned studies have been replicated by other groups, and there has been no study investigating a possible dependence of COVID-19 progression on air quality.

That air pollution has an additional aggravating influence on COVID-19 progression can be postulated as a theoretically plausible hypothesis, but there are currently no direct answers to this question. The relevance of the few studies that have examined the dependence of the progress of therapy for serious diseases on air pollution cannot be conclusively assessed. Treatments for COVID-19 differ from the therapies used in the aforementioned patient cohorts.

It should also be borne in mind that severe cases may be hospitalised for several weeks. The interiors of Swiss hospitals generally have ventilation systems that also filter the air, which should reduce exposure to pollutants during hospitalisation.

Conclusion 4: It can be postulated as a plausible hypothesis that air pollution has an influence on the progression and thus the severity of COVID-19. This hypothesis also depends on and is not completely distinct from Aspect 3. This link could play a role particularly in the early phase before comprehensive therapies are applied. There is currently no direct scientific evidence for this hypothesis with respect to COVID-19. The possible quantitative relevance of the postulated mechanisms cannot therefore be assessed. As pollution levels in Switzerland are low (including during the unusually long period of fine weather this spring) thanks to the air pollution control policies implemented over the past 35 years, and as the number of COVID-19 patients will hopefully remain low, this aspect should not be an epidemiologically significant factor for Switzerland.

Aspect 5: Air pollution and long-term effects of COVID-19

The latest findings suggest that COVID-19 patients may in some cases face serious long-term consequences, with initial reports indicating possible long-term damage to the lungs, kidneys and vascular system.

Position 5 and unanswered questions:

The contribution of air pollution to the development of COVID-19 long-term effects has not yet been investigated. It is also not known whether patients displaying long-term effects will be more sensitive to air pollution in the future. Healthy living conditions, including a clean environment, can have a positive impact on the progression of many chronic conditions. Scientific studies involving COVID-19 patients could investigate the influence of air pollution on the progression of COVID-19's long-term effects. Such studies should take the form of large international research collaborations to ensure that sufficient case numbers and a sufficient diversity of air pollution levels are examined. Case numbers in Switzerland are not really large enough to research these hypotheses. Geographical variations in long-term exposure to air pollutants have been greatly reduced in Switzerland as the relevant limits are largely complied with.

Conclusion 5: The impact of air pollution on the progression of COVID-19's long-term effects is not yet known. However, the postulation of unfavourable correlations is plausible and interactions are conceivable.

Aspect 6: Impact of the COVID lockdown on air pollution

The most important determinants of daily air pollution are 1) the primary emissions of pollutants from various sources, 2) the resulting atmospheric formation of secondary pollutants as well as the breakdown and elimination of pollutants from the air, and 3) the weather conditions. Major emitters of primary pollutants were heavily affected by the lockdown, most notably road and air traffic. Moreover, the lockdown coincided with the longest period of fine spring weather in decades. That period also included a Saharan dust event and a strong Bise (northeast wind) in its first few days as well as the warmest May since records began.

The change in air pollutant levels resulting from the lockdown leads to a corresponding change in the acute effects of air pollution. The impact of changes in pollutant levels on the incidence or aggravation of diseases and mortality could be extrapolated from available data once the lockdown-related change in pollution has been quantified. For example, mortality increases by approximately 1–2% on days when PM pollution is 10 $\mu g/m^3$ higher.

Position 6 and unanswered questions:

In view of the complex relationships between daily air pollution levels, emissions and weather conditions, the impact of the lockdown on air hygiene can only be estimated using mathematical models that take all of these factors into account and compare them statistically with longer time series before and after the lockdown. A direct comparison of data from monitoring stations before and during the lockdown makes sense early on in the process, but is not a sufficient basis on which to make a conclusive assessment of the impact of the lockdown. The quantitative comparison must also factor in the role played by weather conditions. Initial comparisons of these data, both in Switzerland and in other countries, show that the reduction in primary pollutants caused by the lockdown was so marked in some places that it showed up in the data from monitoring stations even without taking weather conditions into account. This is particularly true of the nitrogen oxides and ultrafine particles originating primarily from road traffic or (at locations near airports) air traffic. For PM concentrations that are also heavily determined by secondary processes and sources not affected by the lockdown, the lockdown effect can only be calculated by means of comprehensive modelling. For example, the absolute concentrations increased with the onset of the Saharan dust event at the start of the lockdown, and then decreased with the strong Bise. This increase might have been even more pronounced under normal conditions. The effects on ozone concentrations also require complex modelling, since ozone concentration depends in complex ways on solar radiation and on precursor pollutants, which include nitrogen oxides. Thus, while nitrogen oxides and other precursors form ozone in the presence of solar radiation, nitrogen monoxide – which is emitted along transport routes, for example – actually breaks down ozone. The lockdown could therefore have resulted in a decrease or an increase in ozone concentrations. Initial international studies point to a slight increase in ozone levels, but it is not currently possible to draw any general conclusions about this.

Conclusion 6: The lockdown affected many air pollutant sources and in particular led to a reduction in traffic. The resulting drop in primary pollutant emissions is reflected in exposure levels, mainly those recorded at monitoring locations close to pollutant sources. A precise quantification of the effect of these changes and their impact on health will require data analyses over extended periods, taking into account all other factors affecting pollution (e.g. weather), in order to compare the actual pollution levels with those that would have occurred without the lockdown. An immediate local drop in nitrogen oxide concentrations at locations near roads / streets after the start of the lockdown is well documented, including in Switzerland (by Empa).

Concluding remark

In conclusion, it should be emphasised that, during the COVID-19 crisis, Switzerland has once again benefited from its successful air pollution control policies over the past 35 years. The temporary drop in air pollutant emissions caused by the lockdown shows that there is further scope for improvement. A permanent reduction in air pollutants is vital to achieve a sustained improvement in air quality and thus public health. Emissions of particulate matter, nitrogen oxides, volatile organic compounds and ammonia must be further reduced by consistently promoting and applying state-of-the-art technology in motor vehicles, agricultural and industrial installations, heating systems and other emission sources, both in Switzerland and internationally. Measures must continue to be systematically enforced after the coronavirus pandemic and the improvement in air quality must be verified by standardised measurements. Internationally, Switzerland should work to ensure that the science-based air quality guidelines proposed by the World Health Organization (WHO) for the protection of health are adhered to globally.