

## Environmental Protection Procedures in Improving Air Quality in the University of Dammam Campuses

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### ABSTRACT

**Context:** Campuses of the University of Dammam (UOD) have several sources of air pollution that can adversely affect human health, welfare and the overall efficiency of the educational process.

**Aims:** This study was aiming to assess the role of environmental protection procedures in UOD and evaluate their impact on improving the air quality inside its campuses.

**Settings and Design:** In both the new and old campuses, three different sites were selected to assess air quality level.

**Methods:** Five air pollutants, in addition to environmental noise, were measured at all selected sites. These pollutants included particulate matter less than 10 microns (PM<sub>10</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), volatile organic compounds (VOCs) and nitrogen dioxide (NO<sub>2</sub>). The data were compared to pollutant levels, in the same locations, that were measured during a previous 6-year period, starting from 2008.

**Statistical Analysis Used:** Results of this research were statistically analyzed by the Statistical Package for the Social Sciences (Version 16, SPSS Inc., Chicago, USA).

**Results:** The highest mean  $\pm$  standard deviation of PM<sub>10</sub> (124.5  $\pm$  25.0  $\mu\text{g}/\text{m}^3$ ), CO (1.9  $\pm$  0.7 ppm), VOCs (0.12  $\pm$  0.09 ppm), NO<sub>2</sub> (0.039  $\pm$  0.022 ppm), SO<sub>2</sub> (0.036  $\pm$  0.047 ppm) and environmental noise (71.8  $\pm$  4.1 dB) were found in the old UOD campus. Levels of all pollutants, except environmental noise, during the morning period were higher than those in the afternoon period. In addition, the level of the five air pollutants gradually reduced from 2008 to 2013, and reached to lower than their air quality guidelines.

**Conclusions:** The administrative policies and management procedures of UOD had a positive effect on the level of ambient air quality and reflect the presence of a healthy and safe educational environment inside its campus.

**Key words:** Air quality guidelines, air quality management, ambient air pollutants, traffic pollution, university campus

ملخص البحث:

تهدف هذه الدراسة إلى تقييم دور وسائل الوقاية البيئية في جامعة الدمام وتأثيرها على تحسين جودة الهواء في حرمي الجامعة، القديم والجديد. تم اختبار ثلاثة مواقع في الحرمين للدراسة كما تم قياس خمسة ملوثات هوائية بها بالإضافة إلى الضوضاء كملوث. بينت الدراسة أن مستويات

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جميع الملوثات ما عدا الضوضاء كانت أعلى في الفترة الصباحية مقارنة بالفترة ما بعد الظهر وان مسببات الملوثات الخمسة تناقص تدريجياً بين عامي 2008م و 2013م لمستويات أقل من المستويات المعيارية. خلصت الدراسة إلى أن السياسات والتدابير المنفذة في جامعة الدمام كان لها تأثيراً إيجابياً على نوعية الهواء مما وفر بيئة دراسية صحية وأمنة في الحرم الجامعي.

## INTRODUCTION

Air pollution in urban areas has become an important environmental concern worldwide.<sup>[1,2]</sup> Several urban sources are responsible for the emission of air pollutants. These sources include a rapidly increasing population, dense traffic activity, increase in energy consumption particularly fossil fuels and industrial emissions.<sup>[3-6]</sup> Several adverse effects are strongly linked with both indoor and outdoor air pollution. These effects include respiratory disorders, carcinogenicity and mortality from different cardiovascular diseases.<sup>[1,7-9]</sup> Building discoloration is mainly caused by the deposition of particles, particularly soot, while the deterioration of building is due to the corrosion, oxidation of acidic depositions and the conversions of building materials into more water-soluble ones.<sup>[10]</sup> Efforts should be exerted to prevent or reduce emission of air pollutants and protect health of the inhabitants.<sup>[11]</sup> Implementation of policy measures or administrative actions may lead to significant decrease in the air pollution problem.<sup>[12]</sup>

The air pollution problem inside the university campuses has different sources, including the traffic movement inside the campus, scientific activities in different laboratories and transportation of air pollutants from the near traffic roads or other human activities. Several procedures have been considered to reduce level of air pollutants inside the university campuses. These include increasing the efficiency of ventilation systems and installing of gas monitoring system in the office spaces to ensure that air quality is within the permissible levels.<sup>[13,14]</sup>

The University of Dammam (UOD) is located in Dammam city in the Eastern Province of Saudi Arabia. The old main campus of UOD occupies an area of approximately 525 Ha and lies near the main commercial seaport of the city. It is surrounded on two sides by main traffic roads. More than 4000 cars belonging to students, staff and employees enter the campus on a daily basis.<sup>[15]</sup> A new campus has been built on the coast upwind (before the main roads) to decrease air pollution sources. Air pollution in UOD campuses is a result of traffic movement inside the campus, scientific activities in different laboratories and transportation of air pollutants from highways and roads.

Several initiatives were considered to reduce the level of air pollutants inside the university campuses, including increasing the efficiency of ventilation systems and installing air quality monitoring systems in the UOD campuses to ensure that air quality is within the permissible levels. In addition, policies and administrative actions between 2008 and 2013 have been enforced to reduce air pollution levels in UOD campuses including banning smoking inside the campus, reducing emission sources of air pollution from the university laboratories, traffic movement, increasing awareness of all university members (students, staff and laborers) and increasing green space within the campus, which is considered a good trap of air pollutants. The aim of this study was to assess the role of environmental protection procedures that are applied in UOD to improve air quality inside its campuses.

## METHODS

Simultaneously, in both the new and old campuses, air pollutants at the street level were measured near the main big gates, the side small gates and the main mosques, which are in the middle of the campuses. Inside the old campus, these sites were continuously used as air-monitoring stations during the 5 years of study. Inside the new campus, similar locations were selected to compare the design and locations of the two campuses regarding air pollution levels.

In 2014, five air pollutants, in addition to environmental noise, were measured at the six selected sites in the two campuses. These pollutants were particulate matter less than 10 microns ( $PM_{10}$ ), carbon monoxide (CO), sulfur dioxide ( $SO_2$ ), volatile organic compounds (VOCs) and nitrogen dioxide ( $NO_2$ ). The levels of these pollutants were measured two times per week on working academic days (Sunday to Wednesday): during the morning rush hour (from 7:00 to 9:00 am) and in the afternoon (from 1:00 to 3:00 pm).

Samples of  $PM_{10}$  were collected gravimetrically<sup>[16]</sup> using a mobile Staplex MiniVol® Tactical Air Sampler. After collection on a membrane filter, the  $PM_{10}$  samples were transferred to the laboratory for further analysis. The concentration of  $PM_{10}$  was calculated in micrograms of

the particulate mass per cubic meter of the sampled air volume ( $\mu\text{g}/\text{m}^3$ ).

Levels of the selected gaseous air pollutant were measured directly by two different instruments: The Gray Wolf's DirectSense® mobile PC-based products AdvancedSense™ with WolfPack™ area monitor and the TSI's Q-Trak IAQ Monitor, whereas levels of the environmental noise pollution were assessed by the TES-1352A programmable and calibrated sound level meter. At each measuring point, at least one reading was recorded each 15–30 min for gaseous pollutants in parts per million (ppm) and in decibel (dBA, NR 35) for noise pollution. All results were recorded on a prepared sheet including all items needed for this study such as location, time and description of traffic activity (number of cars per hour).

Data from previous air monitoring surveys that carried out in UOD were obtained from the Department of Environmental Health. These surveys measured the levels of the same five pollutants of the current study on a two-yearly basis, starting from 2008 (i.e., 2008, 2010 and 2012) in the same locations of the old campus and at the same time periods. These data were used to compare current and previous air pollution levels to explore the effect of environmental policies and administrative actions inside the university campuses. Data related to efforts, policies and administrative actions that were implemented to improve the environment inside the UOD campuses were collected from the responsible administrative agencies such as the Department of Security and Safety, the Department of Traffic Management and the Department of Projects and Public Services.

## RESULTS

The highest mean  $\pm$  standard deviation of  $\text{PM}_{10}$  ( $124.5 \pm 25.0 \mu\text{g}/\text{m}^3$ ), CO ( $1.9 \pm 0.7$  ppm), VOCs ( $0.12 \pm 0.09$  ppm),  $\text{NO}_2$  ( $0.039 \pm 0.022$  ppm) and environmental noise ( $71.8 \pm 4.1$  dBA) were found at the main gate of the old campus during the morning period. Likewise, the highest mean level of  $\text{SO}_2$  ( $0.036 \pm 0.047$  ppm) was also found at the main gate of the old campus, but during the afternoon period. The lowest mean levels of  $\text{PM}_{10}$  ( $65.8 \pm 6.6 \mu\text{g}/\text{m}^3$ ), CO ( $0.05 \pm 0.05$  ppm), VOCs ( $0.01 \pm 0.009$  ppm),  $\text{NO}_2$  ( $0.016 \pm 0.005$  ppm),  $\text{SO}_2$  ( $0.01 \pm 0.009$  ppm) and noise ( $57.7 \pm 5.2$  dBA) were obtained near the mosque of the new campus during the afternoon period.

An independent *t*-test was conducted to compare the mean levels of each measured pollutant at the selected

measurement sites in the old and new campuses as shown in Table 1. For  $\text{PM}_{10}$  mean levels, there were no statistically significant differences for all selected sites ( $P > 0.05$ ). For CO and noise, there were statistically significant differences between main gate of the old campus and all the other sites ( $P < 0.01$ ). For the other three pollutants (VOCs,  $\text{NO}_2$  and  $\text{SO}_2$ ), there were no statistically significant differences for most of the studied sites.

As shown in Figure 1, the mean levels of all pollutants, except  $\text{SO}_2$ , were higher during the morning period rather than the afternoon period. Similarly, the mean level of  $\text{PM}_{10}$  was higher during the morning period than the afternoon period ( $116$  and  $88 \mu\text{g}/\text{m}^3$ , respectively). In contrast, the mean levels of  $\text{SO}_2$  and noise were higher during the afternoon period rather than the morning period. There were statistically significant differences ( $P < 0.05$ ) for the mean levels of all pollutants, except  $\text{SO}_2$  [Table 2].

**Table 1: Independent *t*-test for air pollutants levels at different sites in the University of Dammam campuses**

Locations	$\text{PM}_{10}$	CO	VOCs	$\text{NO}_2$	$\text{SO}_2$	Noise
Old main gate-old side gate	0.963	0.000*	0.913	0.492	0.343	0.000*
Old main gate-old mosque	0.697	0.000*	0.004*	0.600	0.001	0.000*
Old main gate-new main gate	0.319	0.000*	0.396	0.274	0.995	0.000*
Old main gate-new side gate	0.758	0.000*	0.363	0.021*	0.961	0.000*
Old main gate-new mosque	0.058	0.000*	0.396	0.107	0.163	0.000*
Old side gate-old mosque	0.732	0.413	0.005*	0.871	0.012*	0.000*
Old side gate-new main gate	0.339	0.656	0.349	0.645	0.376	0.000*
Old side gate-new side gate	0.788	0.593	0.314	0.094	0.391	0.752
Old side gate-new mosque	0.063	0.491	0.349	0.327	0.602	0.768
Old mosque-new main gate	0.512	0.753	0.002*	0.541	0.002*	0.865
Old mosque-new side gate	0.980	0.804	0.001*	0.067	0.001*	0.955
Old mosque-new mosque	0.118	0.944	0.002*	0.258	0.070	0.248
New main gate-new side gate	0.545	0.944	0.987	0.260	0.959	0.776
New main gate-new mosque	0.411	0.819	1.0	0.625	0.189	0.106
New side gate-new mosque	0.159	0.870	0.987	0.530	0.135	0.168

\*Significance:  $P < 0.05$ .  $\text{PM}_{10}$  – Particulate matter less than 10 microns; CO – Carbon monoxide; VOCs – Volatile organic compounds;  $\text{SO}_2$  – Sulfur dioxide;  $\text{NO}_2$  – Nitrogen dioxide

Figure 2 represents the mean levels of the studied gaseous air pollutants in the old and new campuses. Levels of these pollutants, in addition to PM<sub>10</sub> and noise inside the old campus (109.5 µg/m<sup>3</sup> and 66.5 dBA), were higher than those of the new campus (94.6 µg/m<sup>3</sup> and 60.9 dBA). The independent *t*-test [Table 3] showed strong statistically significant differences for the mean levels of CO, NO<sub>2</sub> and noise (*P* < 0.01), whereas there were no significant differences for the other pollutants.

The mean levels of PM<sub>10</sub>, CO, VOCs, SO<sub>2</sub> and NO<sub>2</sub> during the last 6 years, starting from 2008 and including the present study, are presented in Figure 3. It was found that the levels of the five pollutants gradually reduced from year to year, but with different percentages and trends.

The ANOVA test revealed that there were statistically significant differences (*P* < 0.05) for levels of all pollutants, except PM<sub>10</sub>, between the first year of the study (2008) and the other successive periods (2010, 2012 and 2014) [Table 4]. As for PM<sub>10</sub>, there was only a statistically significant difference between the first and last year.

## DISCUSSION

Traffic movement is considered the primary source of the measured air pollutants. For example, airborne PM including PM<sub>10</sub>, are emitted directly from the tailpipe of cars, as a result of friction from tires on the street or indirectly due to the excitation of street dust.<sup>[17]</sup> Emission of CO from vehicles contributes approximately 60% of all emissions, and thus high concentrations of CO generally occur in areas with heavy traffic and congestion.<sup>[18]</sup> The highest mean levels of all pollutants were found at the main gate of the old campus, followed by the other gates of both campuses, whereas the lowest levels were obtained on the street where the mosque is located in the new campus. These results confirm that traffic movement inside the campus is strongly linked with the level of air pollution. This conclusion is based on the difference in the traffic activity in the morning (>200 cars/h) and afternoon (<100 cars/h) periods. The difference in air pollution levels between the two campuses is due to their locations relative to the main traffic road, downwind and upwind, respectively.

The absence of significant statistical differences for PM<sub>10</sub> mean levels between all selected sites (*P* > 0.05) suggests that traffic movement is not the only source of dust in UOD campuses. Construction activity is also considered a main source of air pollutants, particularly PM. For CO and noise, there were strong significant statistical

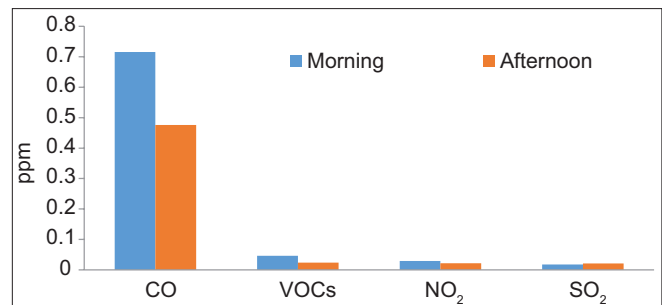


Figure 1: Mean levels of gaseous air pollutants at different periods in the University of Dammam campuses

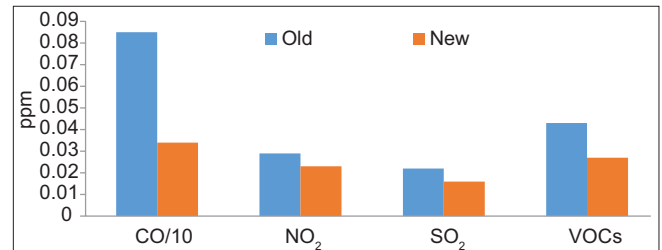


Figure 2: Levels of gaseous pollutants in the old and new campuses of the University of Dammam

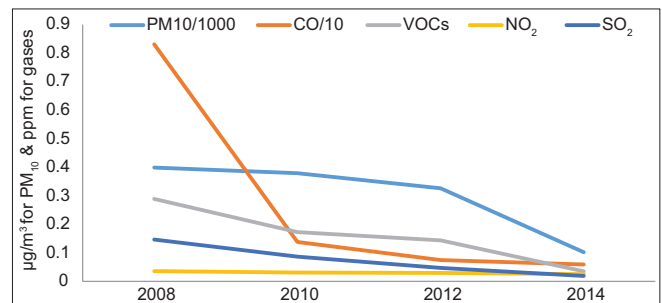


Figure 3: Mean levels of air pollutants during different years in the University of Dammam old campus

Table 2: Independent *t*-test for air pollutant levels at different durations in the University of Dammam campuses

Period	PM <sub>10</sub>	CO	VOC	NO <sub>2</sub>	SO <sub>2</sub>	Noise
AM-PM	0.000*	0.046*	0.010*	0.002*	0.561	0.001*

\* – Significance: *P* < 0.05; AM – Before noon; PM – After noon; PM<sub>10</sub> – Particulate matter less than 10 microns; CO – Carbon monoxide; VOC – Volatile organic compound; SO<sub>2</sub> – Sulfur dioxide; NO<sub>2</sub> – Nitrogen dioxide

Table 3: Independent *t*-test for air pollutants mean levels in the University of Dammam campuses (*P* < 0.05)

Period	PM <sub>10</sub>	CO	VOC	NO <sub>2</sub>	SO <sub>2</sub>	Noise
Old-New	0.052	0.000*	0.092	0.004*	0.166	0.000*

\* – Significance: *P* < 0.05; PM<sub>10</sub> – Particulate matter less than 10 microns; CO – Carbon monoxide; VOC – Volatile organic compound; SO<sub>2</sub> – Sulfur dioxide; NO<sub>2</sub> – Nitrogen dioxide

differences between main gate of the old campus and all the other sites (*P* < 0.01) because the main gate of

**Table 4: ANOVA test for mean levels of pollutants during different years in the University of Dammam campus**

Years	PM <sub>10</sub>	CO	VOCs	NO <sub>2</sub>	SO <sub>2</sub>
2008–2010	0.840	0.000*	0.000*	0.047*	0.000*
2008–2012	0.616	0.000*	0.000*	0.026*	0.001*
2008–2014	0.018*	0.000*	0.000*	0.015*	0.000*
2010–2012	0.641	0.265	0.308	0.207	0.131
2010–2014	0.001*	0.135	0.000*	0.158	0.006*
2012–2014	0.099	0.832	0.003*	0.973	0.390

\* – Significance:  $P < 0.05$ ; PM<sub>10</sub> – Particulate matter less than 10 microns; CO – Carbon monoxide; VOCs – Volatile organic compounds; SO<sub>2</sub> – Sulfur dioxide; NO<sub>2</sub> – Nitrogen dioxide

the old campus has the highest number of cars passing through it, in addition to its closeness to the main road.

Compared to the new campus of UOD, the old campus is characterized by the full capacity of educational, administrative and recreational activities in addition to the expansion and construction of new buildings inside it. As a result, traffic activity inside the old campus is still higher than in the new campus, and for this reason, levels of all pollutants were highest in this campus. The highest level of environmental noise pollution was also found at the main gate of the old campus, followed by the other sites on the same campus and the main gate of the new campus. This is mainly due to the presence of a large number of noise-causing sources inside the campus such as traffic movement and construction of several new buildings, in addition to the movement of all types of vehicles outside the campus.

Activities inside the both campuses of UOD differ considerably. In the early morning, traffic activity inside the both campuses is considered the highest when compared with the other times of the day as all activities start at the same time in the morning but finish at different times. The statistical significant differences ( $P < 0.05$ ) in Table 2, confirm again the significance of traffic activity as the main source of air pollution inside any university campus. The UOD campuses are not far from the first industrial sector of Dammam City, which also increases the level of industrial emissions into the atmosphere.

Several policies and administrative actions were conducted during the past 5 years (2008–2013) to reduce air pollution levels in UOD campuses. For example, several documented traffic laws and new regulations were issued to reduce air pollution and prevent smoking inside the campus. Inspection of all laboratories at UOD, particularly the chemical laboratory, was periodically

conducted. The inspection process included a review of all stored chemicals and disposing of the old or unused chemicals, maintenance of laboratory hoods or suction system and confirming the presence of all required safety tools and procedures. A periodical program for awareness activities, including general environmental lectures, safety workshops, exhibitions, distribution of CDs and educational bulletins, was also undertaken for students, staff and laborers. All defects and design problems of the old UOD campus were studied to avoid a repetition when designing the new campus (e.g., location and size of car parking). Cars and buses owned by UOD were periodically checked and maintained. Those vehicles that were old and noisy and contributed greatly to the level of pollution were replaced. All streets and traffic roads inside the UOD campus were repaired and repaved and the streets and main roads were cleaned daily. The overall area of green spaces in the campuses was increased from 17,000 m<sup>2</sup> in 2008 to 36,575 m<sup>2</sup> in 2013. In addition, garbage and solid waste from all buildings of the campus were collected daily and immediately transported outside the campus to prevent any reactions or emissions into the atmosphere. To study the effect of these policies and procedures, two comparisons were done; the old campus versus the new one and the current year versus the previous 5 years.<sup>[19]</sup> The levels of all pollutants inside the old campus were higher than those of the new one, which reflects the efficiency of these policies and management procedures in improving air quality inside the new campus.

In addition, the levels of the five measured air pollutants gradually reduced from year to year with different percentages and trends. As for PM<sub>10</sub>, VOCs and SO<sub>2</sub>, their levels decreased considerably and reached to below their air quality guidelines (AQG).<sup>[20-22]</sup> Similarly, the levels of CO reduced over time in spite of an increase in the number of cars inside the campus, which reflects the success of administrative policies, particularly those are directed toward traffic arrangement and driving behavior. The reduction in the levels of NO<sub>2</sub> was not significant because the mean concentration of this pollutant was already very low and much lower than its AQG. The statistical significant differences for all pollutants between the first and last year suggests that the administrative policies and management procedures of the UOD had a positive effect on the ambient air quality level inside its campuses.

## CONCLUSION

Our study revealed that the university's administrative policies and management procedures can lead to

improvement of the ambient air quality levels inside their campuses.

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## Conflicts of interest

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