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Limiting the Spread of COVID-19 Based on Monitoring of PM

الحد من انتشار كوفيد 19 بالاعتماد على مراقبة الدقائق المتناهية الصغر في الهواء

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Abstract: In Palestine, the maps of the coronavirus disease 2019 (COVID-19) pandemic issued by the Ministry of Health (MoH), which shows the number of deaths and tested positive cases, have not been able to stop the spread of the disease. Thus; an early warning and decision support system is needed to predict where the infection could happen. In this study, spatial analysis of the number of tested positive cases of COVID-19 indicated that the areas with high levels of Particulate Matter (PM) in the atmosphere were the most affected. PM is closely associated with respiratory diseases and also acts as a carrier of viruses in the air. Accordingly; an affordable mobile system for estimating the levels of PM is designed to warn the user in order to take necessary preventive measures such as wearing a mask or leaving the site. The system consists of a PM sensor, a microcontroller, a power supply, a Bluetooth system, and a mobile application. The findings of this study show that the designed system has a prompt real-time response and a stable operation capable for the protection of human health.

Keywords: COVID-19, Microcontroller, PM, Mobile application, Warning.

المستخلص: في فلسطين ، لم تتمكن خرائط جائحة كوفيد 19 الصادرة عن وزارة الصحة والتي تظهر عدد الوفيات والحالات الإيجابية المختبرة ، من وقف انتشار المرض. لهذا السبب هناك حاجة إلى نظام إنذار مبكر ودعم القرار للتنبؤ بمكان حدوث العدوى. في هذه الدراسة ، أشار التحليل المكاني لعدد الحالات الإيجابية المختبرة لـ كوفيد 19 إلى أن المناطق ذات المستويات العالية من الدقائق المتناهية الصغر في الهواء كانت الأكثر تضررًا. ترتبط هذه الدقائق ارتباطًا وثيقًا بأمراض الجهاز التنفسي وتعمل أيضًا كحامل للفيروسات في الهواء. ووفقاً لذلك؛ تم تصميم نظام متنقل ميسور التكلفة لتقدير مستويات هذه الدقائق لتحذير المستخدم من أجل اتخاذ التدابير الوقائية اللازمة مثل ارتداء الكمامة أو مغادرة الموقع. يتكون النظام من مستشعر للدقائق، متحكم دقيق، مصدر طاقة، نظام بلوتوث، وتطبيق للهاتف المحمول. تظهر نتائج هذه الدراسة أن النظام المصمم لديه استجابة فورية اثناء التشغيل العملي و ومستقر و قادر على حماية صحة الإنسان.

الكلمات المفتاحية: كوفيد 19، متحكم دقيق ، الدقائق المتناهية الصغر ، تطبيق للهاتف ، تحذير.

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INTRODUCTION:

The Palestinian Ministry of Health (MoH) issues pandemic maps and daily briefings about COVID-19 deaths and tested-positive cases in each governorate using the Application Programming Interface (API) code MoH (2023). However, during the past two years (2020 – 2022) the provided information didn't help very much in stopping the spread of COVID-19. Thus; there is a need to develop an early warning and decision support system to help reduce the spread of COVID-19 and other viruses. This is a very crucial issue since the MoH spent a large amount of money as an emergency response to cover the expenses of testing and treatment.

In the United States, it was shown that the increase in death cases caused by COVID-19 was associated with high levels of particulate matter (PM) in the air (Wu et al., 2020). Also, in Japan, according to the Ministry of Health, Labor and Welfare, the places with a large number of death cases COVID-19 (Ministry of Health Labour and Welfare, 2022) were those with high levels of air pollution. PM has a recognized negative effect on the respiratory system and causes both morbidity and high rates of mortality (Nawahda, et al., 2012; Lippmann, 2008, Pope & Dockery, 2006).

Accordingly, the aim of this study was to design a mobile system that enables the user to monitor the levels PM in order to take a preventive prompt action by wearing a mask or reduce exposure by leaving the site where high levels of PM are observed. This study shows the design of the system and illustrates the assembly of the hardware which includes PM sensor (DSM 501A, microcontroller (Arduino Uno), power supply, Bluetooth (HC05) system, and a mobile application programmed for this purpose.

The levels of PM are observed under different conditions to realize the status of air quality. The findings of this study show that designed system has a prompt real-time response and a stable operation capable for the protection of human health.

MATERIAL AND METHODS:

Association between COVID-19 and PM

In Palestine, the analysis of the association between hospital admissions related to COVID-19 and levels of PM is not possible. This is caused by the unavailability of air quality monitoring systems (AQMS) deployed in the governorates. Thus; data sets from Japan were used to examine the association between COVID-19 cases and PM. Japan has a very large number of AQMS for monitoring particulate and gaseous air pollutants, the distribution of the levels of PM all around the country was previously studied in Nawahda (2013). This information is compared with data provided by the MoLHW on the distributions of COVID-19 cases (Ministry of Health Labour and Welfare, 2022) as shown in figure 1. It is found that the places that recorded the highest number of COVID-19 cases were also heavily polluted by PM.

PM monitoring

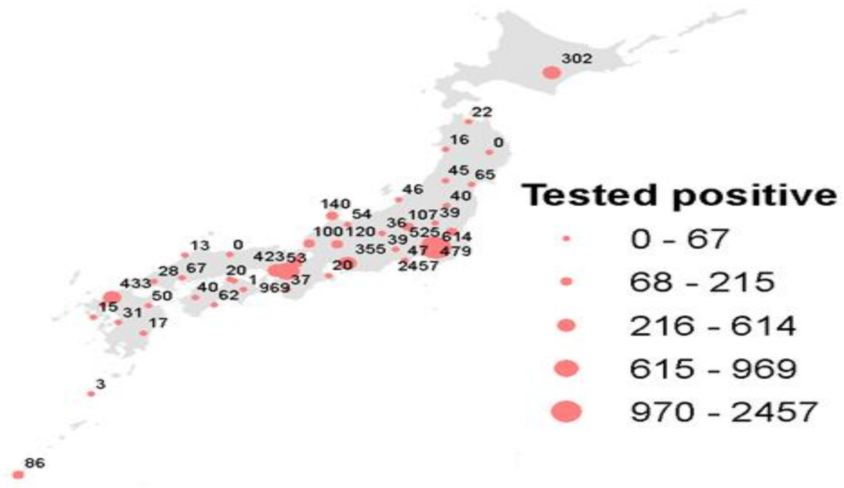


Figure (1). COVID-19 registered cases by MoLHW up to April 16th, 2020, Japan.

The PM sensor (DSM501A) working principle is based on the Lambert-Beer law (Mayerhöfer, et al., 2020) and given by;

$$I=I_0e^{-KcL} \quad \textbf{Eq. (1)}$$

Where I_0 is the intensity of the light at the emitter, I is the intensity of light at the detector, K is the absorption coefficient, L is the distance in the medium, and c is the concentration of the medium .

The obtained measurements from the DSM501A sensor are given by the number of PMs per 283 ml (0.01 cubic ft.), so in order to convert this number to values in micrograms per cubic meters the following parameters should be identified; density of PM that is assumed 1.5 g/cm3, and volume of a PM that can be estimated for different sizes of PMs such as; PM1, 2.5, 10 (particulate matter with aerodynamic diameter ≤ 1, 2.5, 10 μm). Table 1., lists the different statuses of the monitored air.

Table (1). Statuses of air based on the number of PM

Status	Levels of PM (ug/ 0.01 cft)
Clear	<=1000
Good	>1000 and <=10,000
Acceptable	>10,000 and <=20,000
Heavy	>20,000 and <=50,00
Hazard	>50,000

Hardware assembly

The circuit of the hardware and the corresponding flowchart for programming the microcontroller and linking it with the components of the hardware are illustrated in figure 2 and 3, respectively. The DSM501A sensor estimates the analog signal of PM and transfers it to the Arduino Uno microcontroller to convert it to a digital signal. The working principle of DSM501A can be found in (Wang, et al., 2017).

The Arduino Uno passes the digital signal to the mobile application by the Bluetooth integrated circuit. A mobile application is programmed to display the levels of PM at the mobile phone and to show the quality of air based on Table 1. and accordingly displays a warning message.

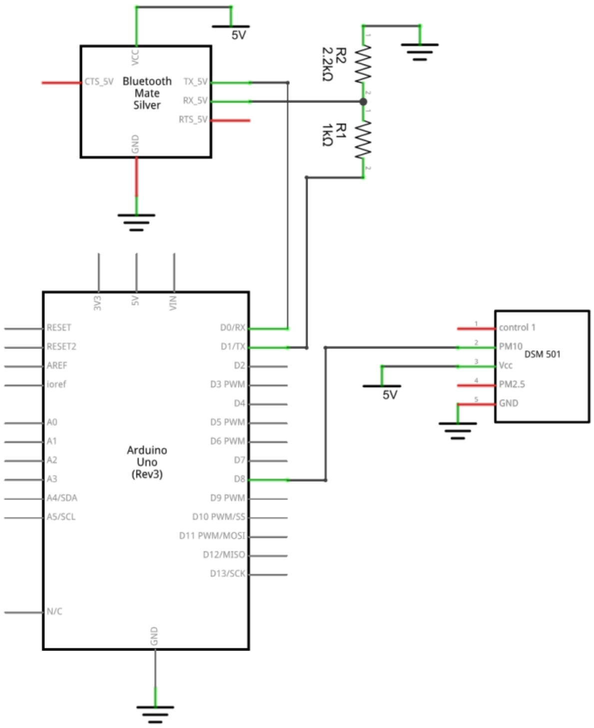


Figure (2) Circuit of the hardware connection used for assessing the status of PM levels in air.

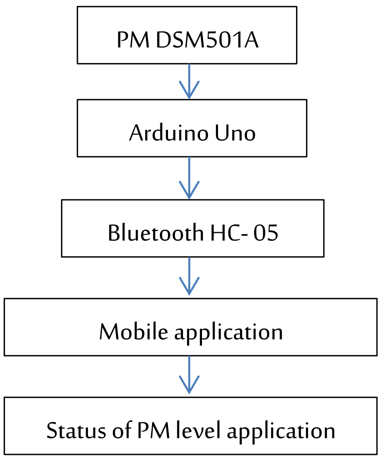
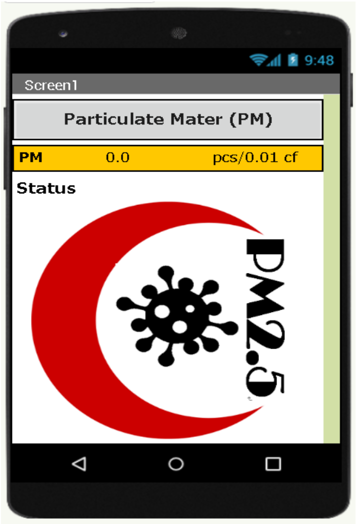


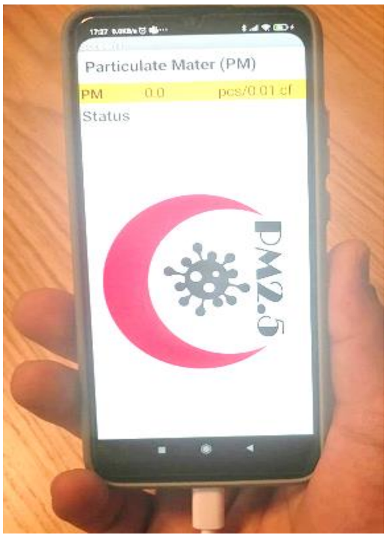
Figure (3) Flowchart of the programming of the Arduino-Uno microcontroller with the mobile application.

Software design

The Arduino Uno microcontroller is programmed to obtain, analyze, and transfer the levels of PM in the sampled air to the mobile application. These tasks are as follows: first; time initialization to set when to run and when to stop the sampling, second: data acquisition and processing where signals are amplified, filtered, and digitalized, and third; transfer of the digital signals to the mobile phone by using a Bluetooth system. The MIT-APP inventor is used to analyze the data and then to issue a warning message based on Table 1 (figure 4).

(a)



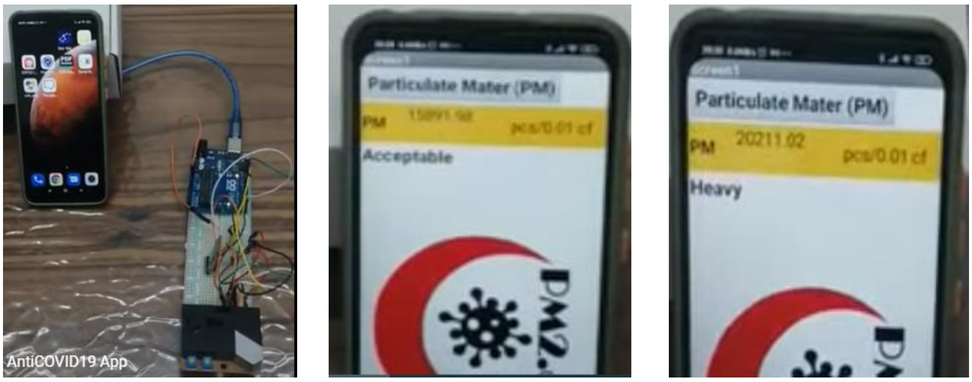


(b)

Figure (4) The mobile application design (a) and mobile application uploaded into a mobile phone (b).

RESULTS AND DISCUSSION:

The PM mobile monitoring system is tested under various air quality conditions. The prompt response of the system is illustrated in figure 5 where the status of air changes from "Acceptable" under normal air quality conditions to "Heavy" once smoke is applied.



(a) (b) (c)

Figure (5) Testing of the designed system in (a) under different conditions; (b) under normal condition

, and (c) after putting the system closed to a smoke source.

The obtained results could be conservative since the system should be calibrated on site by using any type of certified AQMS in order to compare the results from both systems; however, such systems are unavailable in Palestine. Additionally; the presented levels of PM could be reevaluated to be in micrograms per cubic meter in order to compare them with the U.S.EPA $PM_{2.5}$-guidelines (U.S. EPA, 2022); 15 $\mu g\ m^{-3}$ / 35 $\mu g\ m^{-3}$ (mean annual standard / 24 hours standard), and the World Health Organization-Air quality Guidelines (WHO-AQG); 10 $\mu g\ m^{-3}$ / 20 $\mu g\ m^{-3}$

(World Health Organization. Occupational and Environmental Health Team, 2006).

CONCLUSION:

In this study, a system for real-time monitoring of PM levels in the air is designed and operated under different conditions. It is simple, affordable, and helps protect human health, especially from infectious diseases like COVID-19. The system consists of the following items; a PM sensor (DSM 501A, microcontroller (Arduino Uno), power supply, Bluetooth (HC05) system, and a mobile application programmed for this purpose. The practical testing of the systems under different air conditions shows that it has a prompt real-time operation. The system could be upgraded to monitor other gaseous air pollutants. Also; a stationary version of the systems could be deployed based on Internet of Things (IoT) applications to provide live air quality monitoring.

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