Monitoring the Biological Safety Indoors

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Abstract. This paper proposes a method and a device for monitoring biological contamination indoors. The method uses the human body as a primary transducer as it produces a psychosomatic response to a biological agent. It is based on measuring the psychosomatic response to the non-invasive effects of biologic threats posed by such agents. A light permeability sensor for human body is proposed as for psychosomatic response instrumentation. The paper presents the circuit diagram of the device and describes it. It further dwells upon the specifications of an experimental unit created to measure biological contamination. The paper discusses the results of measuring human body’s psychosomatic response to pathogenic molds present indoors. It proves the proposed biological monitoring method advantageous.

1. Introduction
Using state-of-the-art control methods and devices to keep humans safe in their habitat is a key aspect of safety in the technosphere. Human habitat, anthropogenic and technogenic effects might cause a biological contamination of residential or industrial space, which jeopardizes human health. Fungi, especially mold, are among the most common biologic threats to human. Long exposure to mold causes severe human diseases, including cancers [1]. The danger lies in the fact that such agents might grow undetectably for a long time in hard-to-reach places.

Such agents must be detected in time to keep human habitat safe.

There are many methods for diagnosing biological contamination. The most common ones are based on inoculating the sampled cultures in Petri dishes. These methods perform well; however, they require extensive laboratory research [2]. Fluorescence is commonly applied in a variety of applied biological and biomedical studies [3]. It is a fast and accurate method for testing biological agents [4]. State-of-the-art X-ray fluorescence (XRF) spectrometers have undeniable advantages over other known devices, such as being small and lightweight; they can perform express tests in the field [5]. However, XRF spectrometers are costly, and the tested object must be prepared accordingly before running a test.

The goal hereof is to develop an efficient method for monitoring the biological safety indoors.

2. Materials and Methods

2.1. Diagnosis Method
The method selected for detecting biological contamination indoors is the one proposed in [6, 7]. The method is based on how field-effect structures of agents affect thos of humans. If an agent penetrates the field-effect structures of a human person, the person’s psychosomatic state alters for a short time.

If the agent is a pathogen, the psychosomatic state worsens. Such worsening is indicated by muscular response. Muscular response is well-registered by measuring the photoconductivity of human body.
parts. It is known [6] that a negative effect will dim the luminous flux passing through human body, a sign of a pathogen.

A utility model [8] is proposed herein for measuring the psychosomatic response. Figure 1 shows the device (tester) for monitoring the biological contamination indoors, as well as its circuitry.

![Figure 1. Biological contamination monitor (tester): (a) general view; (b) circuitry](image)

The device comprises (Figure 1b) a microcontroller, *MCU*, a power-up switch, *S1*, a start button, *S2*, and an LED, *VD1*, as well as psychophysical response indicators, *VD2* to *VD6*, batteries and a charger in a separate enclosure, *I*, and an external photoconductivity sensor, *2*. The sensor is enclosed in a pin. The pin contains the light emitter *VD7* on one side, and the light receiver *RT1* (a photoresistor) on the other side. *RT1* is in one of the arms of a voltage divider. The output voltage of the latter goes to the analog input *A1* of the microcontroller *MCU*.

The tested agent must be prepared before testing. Place the agent in a test tube and seal it. Before measurement, place the tube with the agent at an arm’s length from the operator running the test. This will minimize the operator’s exposure. Then the operator should attach the sensor to their finger, press *S1*, then *S2*. Pressing the start button *S2* will start the measurement. First, the device calibrates itself. The microcontroller samples 500 voltage readings from the photoconductivity sensor over 5 seconds, averages it, and stores the resulting value *U*n in the memory. Then the process repeats. The newly received value *U*n+1 is compared to the previous one. The process repeats until -1% < (*U*n - *U*n+1)/*U*n < 1%. The device will light up the yellow LED *VD4*, which means the calibration is complete. That infers that the operator’s psychosomatic state has stabilized and can now be taken as the baseline. The last computed *U*n becomes the baseline *U*0 and is stored in the memory: *U*0 = *U*n.

When the yellow LED *VD4* lights up, the device begins measuring the operator’s body response to the agent. To that end, the operator should take the test tube in their unoccupied hand. The author’s original research has shown the body begins to respond within 10 to 20 seconds. This is why the microcontroller will read the light sensor output voltage *U*1 after enough time has passed for the psychosomatic response to peak. The device then calculates the relative deviation Δ: \( \Delta = \frac{(U_0 - U_1)}{U_1} \). If \( \Delta < -6\% \), the outer red LED *VD2* will light up, a sign of strong exposure to a negative effect of the agent on the operator’s psychosomatic state. If \(-6\% < \Delta < -1\%\), the inner red LED *VD3* lights up, a sign of moderate exposure to a negative effect of the agent on the operator’s psychosomatic state. If \(-1\% < \Delta < 1\%\), the red LED *VD4* lights up, a sign of a neutral effect. If the inner LED *VD5* or the outer green LED *VD6* lights up, that means the agent has a weak or strong positive effect on the operator, respectively. Thus, this method can detect negative exposure.

### 2.2. Agent Examination Method

Biology knows of thousands of mold species that can colonize human habitat. Some of them might go unnoticed for a very long time, as they grow in dark, in ventilation shafts, or in hard-to-reach humid places.
Aspergillus, Alternaria, Stachybotrys are mold fungi that are most dangerous to human. Regardless of what toxic mold species it is, all of them affect human psychosomatics negatively. Thus, psychosomatic response can be measured to detect toxic mold.

The proposed examination procedure is as follows. In the tested room, sample material from the places of alleged mold infestation. Place a tampon with the sample in a glass test tube. Take a comfortable position at a desk with the tester (Figure 1a) and the test tube. Before testing, place the tube at an arm’s length away from the operator. Then attach the photoconductivity sensor to a left-hand or a right-hand finger as shown in Figure 1a, power up the tester and press S2. The single red LED VD1 lights up briefly, and calibration begins. The same LED will light up against when calibration is over. The microcontroller will then switch to measuring. Immediately place the tube on the hand next to the sensor and wait until VD1 goes off. As soon as it happens, the microcontroller will calculate the difference between the current reading and the baseline; the result will be displayed by an LED, VD2 or VD3. If one of the two red LEDs lights up, VD2 or VD3, then the tube contains a toxin. It also indicates the degree of toxicity. VD2 stands for maximum toxicity.

3. Results
To test the method for monitoring the biological safety indoors, the team ran experiments with Stachybotrys, or black mold.

The first step was to prepare biomaterial for the experiment. Mold was placed in two Petri dishes. One was exposed for two weeks to an electromagnetic signal at a frequency that kills this kind of mold. Thus, mold was killed in one dish (Figure 2a) and reproduced in the other one (Figure 2b). Microscopy showed newly formed gray-white spores, see Figure 2b.

![Figure 2. Mold: (a) exposed to an electromagnetic signal at a fatal frequency; (b) normally grown](image)

Step 2 was to place the mold from the two Petri dishes into two different test tubes. Tube 1 contained deactivated mold, while Tube 2 was for the living one. This was a blind test, as the tubes were marked but could not be distinguished by eye. The contents of each tube was tested 50 times. Table 1 presents the test results.

| Relative deviation $\Delta$, % | $\Delta<6$ | $-6<\Delta<-1$ | $-1<\Delta<-1$ | $1<\Delta<6$ | $\Delta>6$ |
|-------------------------------|------------|----------------|----------------|--------------|------------|
| Test tube 1                   | 0          | 4              | 43             | 3            | 0          |
| Test tube 2                   | 35         | 12             | 3              | 0            | 0          |

Contamination was considered high at $\Delta<-6$ or low at $-6<\Delta<-1$.

Multiple experiments showed the psychosomatic response measurement error was mainly random. At $n = 50$ ($n > 20$) measurements, the experiment could be considered statistically solid. That
minimized random error and maximized the significance of measurements, i.e. they mostly hit the preset measurement range.

4. Discussion
In Tube 1, 1 4 of the 50 measurements returned a “red” result ($\Delta < -1\%$). This meant a 92% probability of zero pathogens being present in the tube. In Tube 2, 47 of the 50 measurements returned a “red” result ($\Delta < -1\%$). This meant a 94% probability of a pathogen being present in the tube. The measurements thus confirmed a high probability of detecting a toxin in the test sample.

The method could be improved by further research into refining the calibration procedure, the exposure time, and the measurement intervals.

The proposed method for monitoring the contamination indoors has some advantages, as it:
- requires no special training;
- can be used to monitor multiple complex objects at a low cost;
- is fast, as it only takes a few minutes to diagnose the presence of mold;
- is easy and convenient to perform, as it requires no special preparation of samples;
- uses a low-cost device that is also portable and lightweight.

The cons are:
- inability to identify the type of pathogen, which will require further laboratory tests;
- the operator might be exposed to unrelated negative impacts, which will require longer calibration as the operator will take time to calm down.

The proposed method and the device of our design can detect fungal or sundry biological infestation indoors in a timely fashion.

5. Conclusions
An efficient method has been proposed to monitor the biological contamination indoors; the method is based on reading human’s psychosomatic response.

A prototype has been made for quick tests, proven reliable by experimenting on Stachybotrys (black mold).

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