Project Based Learning: A Study of Using ZnO on Bacterial Species

Onur Berdici[1], Kerem Çoban[2]

Hisar School İstanbul, Turkey[1,2]

Abstract

Project-Based Learning is an instructional methodology that encourages students to learn and apply knowledge and skills via experience. The role of the teacher is shifted to the students and students work more independently through the whole process. System gives opportunities to students to build 21st century skills as collaboration, communication, critical thinking, and the usage of technology, which will serve them well in the workplace and their later life. Learning becomes deeper and long-lasting, and inspires students a love of science even in tough subjects. This project involves an alternative preservative for raw foods by preventing bacterial growth with ZnO photocatalyst in the presence of UV light. In this study, all the literature survey and experimental procedure are performed by us in a laboratory environment and the project has brought new information in the fields of both chemistry and biology. We believe in as Swiss Psychologist Jean Piaget says, "knowledge is a consequence of experience".

Keywords: *project based learning, ZnO, food hygiene, bacteria.*

1. Introduction

Project-Based Learning is an instructional methodology that encourages students to learn and apply knowledge and skills via experience. The role of the teacher is shifted to the students and students work more independently through the whole process. System gives opportunities to students to build 21st century skills as collaboration, communication, critical thinking, and the usage of technology, which will serve them well in the workplace and their later life. Learning becomes deeper and long-lasting, and inspires students a love of science even in tough subjects (John W. Thomas, 2000). PBL is an innovative approach which teaches a multitude of strategies critical for success in the 21st century. Students drive their own learning through inquiry, as well as work collaboratively to research and create projects that reflect their knowledge (Bell Stephanie, 2010). It was found to be more effective on students' academic achievement levels and attitudes towards the course than the activities instruction based on student textbooks. Students do not memorize the concepts and other things, they do study the learning materials and learn deeply (Baş Gökhan, 2011).

In this project, the analysis of the solutions containing E. coli and S. aureus was examined in the presence of ZnO semiconductor. The possibility of stopping the growth of or even destroying the targeted bacterial species in the presence of ZnO, an alternative semiconductor to TiO_2 was investigated.
Recently, different photocatalysts have been used to eliminate released dyestuffs in wastewater in the textile industry, taking into account different conditions. Dyes have a carcinogenic effect on humans and cannot be removed from water by conventional treatment methods such as aerobic decomposition, flocculation, adsorption in activated carbon, ozonation and chlorination. Therefore, advanced oxidation methods such as photocatalytic degredation are preferred (Stylidi M., Kondarides D., Verykios X., 2003).

Poor sterilization of food contact surfaces, equipments and processing environments creates the perfect environment for diseases, and can have dangerous consequences. Improperly cleaned surfaces unfortunately support the development of bacterial biofilms. (R. A. N. Chmielewski, J. F. Frank, 2003).
This study involves usage of an alternative semiconductor ZnO, on E. coli and S. aureus bacterial species in the presence of UV light. The effectiveness of the antibacterial activities of the semiconductor was analyzed with and without UV light and the results obtained were interpreted.

1.1. Zinc Oxide (ZnO)

Zinc oxide is a granular, powdered product and is used as a raw material in the rubber, cosmetic, petroleum, ceramic, glass and coating industries. In the textile industry, it is used to remove azo dyes from waste water and used in the production of linoleum and enamel. It is an odorless, white powder, has a bitter taste. (Jean-François Pilichowski, Pierre Boule, 2001). UV-activated reactions of semiconductors are important because of the production of electron- hole pairs, and each semiconductor has a different bandgap energy value. Figure 1 represents the light-activated reaction mechanism of ZnO.

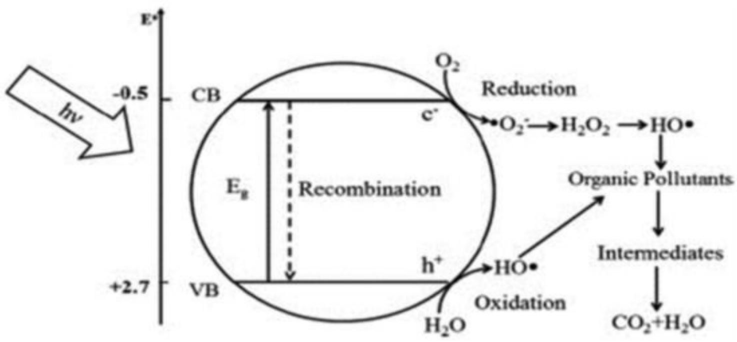

Figure 1: UV Light Activated Reaction Mechanism of ZnO

1.2. Escherichia *coli*

Escherichia coli (E. coli) bacteria normally live in the intestines of healthy humans and animals (Figure 2). Most E. coli varieties are harmless or cause a relatively short diarrhea. However, several types can cause severe abdominal cramps, bloody diarrhea and vomiting. E. coli can be exposed through contaminated water or food, particularly raw vegetables and uncooked meat products (Zimmer, Carl, 2008).

Figure 2. E. *coli* Colonies on Blood Agar

1.3. Staphylococcus *aureus*

Staphylococcus aureus (S. aureus) is responsible for most hospital-based infections (Figure 3). Despite the wide use of disinfectants such as peracetic acid in health institutions, this bacteria should be considered. They are common microbes in the skin, mainly formed on the nose of healthy people. Treatment usually involves the drainage of the infected area and using antibiotics. However, some Staph infections no longer respond to common antibiotics (Matthew Wook Chang, Freshteh Toghrol and William E. Bentley, 2006).
Food-related intoxications have been found to be the most important factor in the transmission of S. aureus to humans. Human beings are the carriers and they transport this bacteria to other people and foods. (Argudin MA, Mendoza MC, Rodicio MR., 2010).

Figure 3. S. *aureus* Colonies on Blood Agar

2. Method

This research project focuses on the use of semiconductors for the elimination of bacterial species. E. coli and S. aureus were selected as target bacteria species and experimental setup, semiconductor usage and amount of semiconductor were determined and their efficiencies were analyzed.
4 experiment sets were prepared by adding 0.05 g of catalyst to 50 mL of 0.5Mc of Farland aqueous bacteria solution at room temperature (Table 1). A pyrex erlenmeyer was used for irradiation experiments (Figure 4). Samples were taken at certain time intervals for 2.5 hours irradiation, and bacteria solutions were filtered by a millipore filter (100 mm pore size) and analyzed by on blood agars. Each blood agar was left in the N025 model Core Brand incubator for 24 hours at 37°C. In all experiments, bacterial solutions were mixed with a Velp Scientifica magnetic stirrer.

Figure 4. Experimental Set-up (bacteria solution in the presence of ZnO and UV light)

Table 1: 4 Different Sets Used in Experiments

Set Number	Bac. Species	BaC Conc.	Volume (mL)	Mass of ZnO (g)
1-Control Group	E. *coli*	0,5Mc Farland	50mL	------
2	E. *coli*	0,5Mc Farland	50mL	------
3	E. *coli*	0,5Mc Farland	50mL	0,05g
4	E. *coli*	0,5Mc Farland	50mL	0,05g
1-Control Group	S. *aureus*	0,5Mc Farland	50mL	------
2	S. *aureus*	0,5Mc Farland	50mL	------
3	S. *aureus*	0,5Mc Farland	50mL	0,05g
4	S. *aureus*	0,5Mc Farland	50mL	0,05g

3. Conclusion

The combination of ZnO and UV light increased the effectiveness of inactivation and reduced the time required for the process and created a new advantage in terms of health safety for raw food products. Control group experiments showed growth in both bacterial species, whereas ZnO's interaction with UV light showed inhibitory effect on both E. coli and S. aureus (Table 2).

Table 2. Development of Bacterial Species of 4 Sets
(First 80 min in 5 min intervals ✅ bacteria developed, ⛔ no bacteria formation)

		Time (min)														
Set #	Bac. Species	5	10	15	20	25	30	35	40	45	50	55	60	65	70	80
Control Group	E. *coli*	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅
2- UV	E. *coli*	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	⛔	⛔	⛔
3-ZnO	E. *coli*	✅	✅	✅	✅	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔
4-(UV +ZnO)	E. *coli*	✅	✅	✅	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔
Control Group	S. *aureus*	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅
2- UV	S. *aureus*	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	⛔	⛔
3-ZnO	S. *aureus*	✅	✅	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔
4-(UV +ZnO)	S. *aureus*	✅	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔	⛔

ZnO alone or UV light alone has antibacterial effect to suppress the growth of Gram-positive and Gram-negative bacterial species, but with UV light, efficiency is optimal.
In this study, the sensitivity of both Gram-negative and Gram-positive bacteria may be caused by the formation of reactive species originating from electron-hole pairs coming from ZnO semiconductor. Reactive species attack cell wall of E. coli and S. aureus and cause cell death. Teachers should offer different projects to students so that students have a chance to select from a number of subjects. Moreover, researches can be carried out in different lessons and institutions, students interact face to face with each other and share the responsibility of the learning process. All the literature survey and experimental procedure are performed by us in a laboratory environment and the project has brought new information in the fields of both chemistry and biology. We believe in as Swiss Psychologist Jean Piaget says, “knowledge is a consequence of experience”.

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