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Original Paper

Development of an innovative and original portable pipette with different filtration layers for water purification

İkra Kuyumcu[a], Ozan Yağmuroğlu[a,*]

[a]*National Defense University, Air Force Academy, Department of Chemistry, İstanbul, 34149, Türkiye.*

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ABSTRACT

The environment is the external environment in which living creatures on Earth constantly interact throughout their lives. Any negative situation that may occur in the environment greatly affects living life. Increasing industrialization and urbanization along with the ever-increasing population are the main causes of environmental pollution. Water pollution covers the negative effects on the physical, chemical or biological properties of water as a result of human activities. The pollution of water, which is of vital value for living things, due to different factors every day, causes the decrease in potable water resources. In our study, a portable pipette was designed to use different water sources as drinkable water. Four different filter layers were used in the pipette we designed. Filter layers used; coarse filter, activated carbon, magnetic nanoparticle and silver nanoparticle (AgNP). Magnetic nanoparticle and silver nanoparticle were synthesized within the scope of our study. The performance of the purification pipette we developed was investigated with samples containing methyl parathion at different concentrations. In our study, a UV-Vis spectrophotometer was used as an analysis device. As a result of the analyses, it was found that the pipette we developed could purify around 65%, regardless of the concentration of the analyte. The portable purification pipette we developed in our study is promising in terms of making water resources found in nature drinkable, especially in military operations.

I. INTRODUCTION

Environmental pollution affects ecosystems by polluting the physical and biological components of the earth and atmospheric system, and pollution manifests itself as a global problem. This pollution, which also affects biodiversity, poses a serious threat to living things. The quality of life of living things, from single-celled creatures to multi-celled organisms such as plants, animals and humans, depends on the quality of air and water resources [1]. Due to the rapid increase in industrialization and urbanization, environmental pollution has alarmed the world [2]. In addition, the ever-increasing needs of people have facilitated the release of more hazardous waste into the ecosystem. Water pollution is one of the global problems that threatens the sustainability and development of people and society [3]. Nowadays, the quality of water has deteriorated and water pollution has occurred due to different organic and inorganic pollutants. Heavy metals are examples of inorganic pollutants due to their harmful effects on living health [4]. It is known that many heavy metals have toxic and carcinogenic properties. Additionally, heavy metals tend to accumulate in living organisms [5]. Another class of pollutants are polycyclic aromatics (PAHs), organic pollutants released by oil spills and pesticides, herbicides, personal care products and pharmaceuticals [3]. Domestic sewage, urban and industrial wastes, agricultural wastewater are the main causes of organic pollution in water [6]. Dosages of organic pollutants that may cause health problems have been found in both ground and surface water [3]. High pollution rates in water resources in recent years have created concern for the whole world. The emergence of new products and industrial technologies has led to the generation of new

*Corresponding author. Tel.: +90-212-663-2490; e-mail: oyagmurog@hho.msu.edu.tr

wastes. This situation poses a great risk for human health and ecology if waste is not managed correctly [7]. The effects of pollutants on humans can reach very serious and life-threatening levels, such as hypertension, emphysema, kidney damage, neurological diseases and cancer [8]. In addition, these pollutants are known to have harmful effects on the aquatic ecosystem [3]. In order to prevent these negativities caused by pollutants, removing organic and inorganic pollutants from water is a very important and urgent need [8]. In addition, water treatment is also important in order to avoid a shortage of clean and safe water and to ensure continuous use of water [9]. Some of the methods applied for the treatment of pollutants in water are adsorption, chemical treatment, advanced oxidation and biological oxidation methods [3]. Techniques used to remove pollutants from water are generally divided into three different categories: biological, physical, and chemical. Biological treatment refers to the removal of biodegradable chemicals from the environment. Physical purification uses the principle of using physical forces. Physical methods include nanofiltration, electrodialysis, and reverse osmosis. Chemical treatment is a treatment method in which pollutants are removed from the environment as a result of chemical interactions. Precipitation, adsorption, and disinfection are used in chemical treatment. Adsorption is the adhesion of a substrate in a gas or liquid phase to the functional group of the adsorbent surface through various intermolecular forces. This process continues until the adsorbent surface reaches maximum saturation [10]. Adsorbents are materials to which molecular species adhere to the surface and may be of synthetic origin. Selection of the appropriate adsorbent for treatment is a critical factor to ensure maximum pollutant removal, as it directly affects treatment efficiency. Some of the adsorbents commonly used to remove pollutants are chitosan, zeolites, mesoporous silica, activated carbons, cyclodextrins, and carbon nanomaterials [3]. Adsorption is one of the most popular methods used to remove pollutants from wastewater due to its low cost, easy to use, environmentally friendly, low health risk and harmless properties [11]. Nowadays, environmental pollution has become an area of concern due to its destructive effect on living life. Different treatment materials and systems have been developed from time to time to combat this serious problem.

Activated carbons are one of the best solutions for the removal of pollutants from water and the atmosphere, as they are carbonaceous materials with high porosity, large surface area and select functional groups necessary for the removal of pollutants [11]. Activated carbon is used to remove heavy metals from water sources [12]. Nanomaterials, which will be used as the third filter, are highly preferred in water purification applications due to their large surface area-to-volume ratio and extraordinary properties [13]. Nanomaterials successfully remove heavy metals, organic pollutants, inorganic anions and bacteria from solutions [14]. Some of the advantages of nanomaterials; It has specific surface areas, rapid dispersion, high reactivity and adsorption capacity for different organic pollutants, heavy metals and bacteria [15]. Silver nanoparticles (AgNP) to be used as the final filter have strong antimicrobial properties. It is known that the antibacterial activity of AgNPs is higher than that of silver ions [16]. Antimicrobial compounds are compounds that suppress or inhibit the growth of microorganisms [17]. AgNPs added to filter materials are considered promising for water disinfection due to their high antibacterial activity and cost-effectiveness [18].

Various scientific studies are carried out in our country to evaluate water quality and eliminate its pollution [19-22].The purification pipette we developed contains different adsorbents for the removal of all kinds of pollution. In this respect, it has advantages compared to similar studies in the literature. Solid particles in drinking water are removed by a coarse filter. Various organic pollutants in the environment are removed by the porous structure of activated carbon and chemical interactions. Some organic and inorganic pollutants in water are eliminated by using magnetic nanoparticles. Finally, biological pollutants in drinking water are purified with silver nanoparticles.

Methyl parathion was used as analyte in calculating the purification efficiency. The molecular formula of methyl parathion is $C_8H_{10}NO_5PS$ and it is one of the insecticides with high toxicity and its molecular weight is 263.21 g/mol. Methyl parathion shows its effect by inhibiting AChE, which breaks down acetylcholine. Methyl parathion is one of the insecticides with high toxicity according to the classification made by EPA (Environmental Protection Agency). It is highly lipid soluble and therefore is rapidly absorbed through the skin, respiratory and digestive tract. Most of the methyl parathion is excreted through urine and some through feces. The structural formula of methyl parathion is shown in Figure 1.

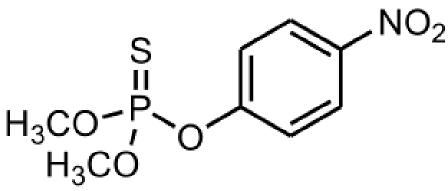

Figure 1. Structural formula of methyl parathion

In our study, it was aimed to develop a portable, original and innovative straw in order to make water obtained from different sources drinkable. Considering the presence of different pollutants in water sources, four different purification layers were placed in the pipette system. Coarse filter, activated carbon, magnetic nanoparticle and silver nanoparticle were used as filtration layers. Each layer is effective in removing different pollutants from the environment. Methyl parathion was used as analyte to determine the performance of the developed purification pipette. Within the scope of our study, standard solutions containing methyl parathion were prepared, and then these samples were passed through the pipette system we designed. The analysis of the standard solution before the filtration process was made with a UV-Vis Spectrophotometer, and the purification efficiency after filtration was monitored with the same device. The analytical performance of our system was determined by monitoring the decrease in absorption value.

II. EXPERIMENTAL METHOD

2.1 Instrumentation

In the sample preparation process, Shimadzu ATX224R analytical balance, Ohaus Starter 3100 ph meter, KUDOS SK 3310 HP ultrasonic water bath, DLAB MX-S Vortex were used. Analyzes were carried out with a P&G T60+ model Uv-Vis Spectrophotometer.

2.2 Chemicals

Ultrapure water obtained from the Elektro-Mag Laboratory Water Still M4 brand pure water device was used in the sample/standard preparation processes and cleaning of glassware within the scope of our study. All chemicals used were obtained from Sigma-Aldrich (Germany).

2.3 Magnetic Nanoparticle Synthesis

Magnetic nanoparticles were synthesized according to a study in the literature [23]. 1.961 g of $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$ and 2.703 g of $FeCl_3 \cdot 6H_2O$ were dissolved in 100 mL of ultrapure deionized water and the solution was heated to 80 °C with vigorous stirring. Then, 1.0 mL volume of concentrated stearic acid was added dropwise into the solution. It was observed that the color of the solution changed from brick color to black-gray. The reaction continued for 2 hours at 80 °C in a nitrogen gas environment. The resulting nanoparticles were repeatedly washed several times with ultrapure water and ethanol to remove excess acid and synthesis byproducts. The magnetic nanoparticles were then kept in an oven at 50°C for 24 hours to dry. The image of the resulting magnetic nanoparticle is presented in Figure 2.

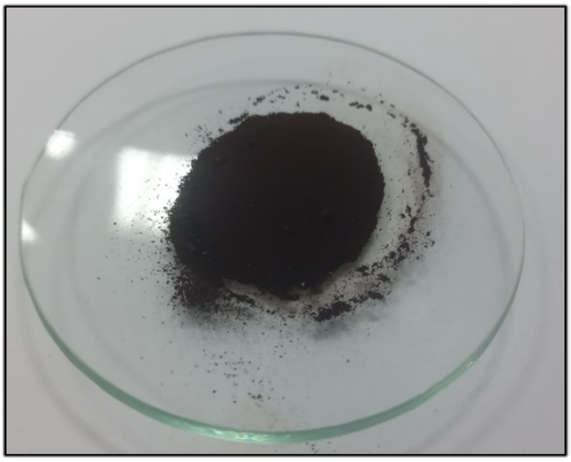

Figure 2. Magnetic nanoparticle

2.4 Silver Nanoparticle Synthesis

In our study, silver nanoparticles (AgNPs) used as filtration layer were obtained by through an originally developed green synthesis. Clove extract was used as the reducing chemical source used in the synthesis of silver nanoparticles. For this purpose, firstly, 5 g of cloves were ground into powder in a grinder. Then, 100 mL of pure water was added to 5 g powdered cloves and the mixture was heated until it reached the boiling point. After boiling was observed, the heating process was terminated and the sample was left to cool. The mixture was left to cool at room temperature for 24 hours and was filtered three times with filter paper with 3 different pore diameters. First, filtration was done with a coarse filter, then 110 mm diameter filter paper was used, and finally the sample was passed through 45 mm diameter filter paper. The obtained clove extract is shown in Figure 3.

Figure 3. Clove extract

For silver nanoparticle synthesis, 100 mM silver nitrate solution was prepared. For this purpose, 0.17 g of $AgNO_3$ was weighed and dissolved in 10 mL of pure water. Volume optimization was performed to determine the extract volume to be used for AgNPs synthesis. In volume optimization, the volume of silver nitrate was kept constant at 1 mL and the total volume was 50 mL, and the extract volume was changed in the range of 0.5-4 mL. The presence of the formed AgNPs was monitored by UV-Vis Spectrophotometry. The absorbance values obtained against the changing extract volume were plotted. The resulting graph is presented in Figure 4.

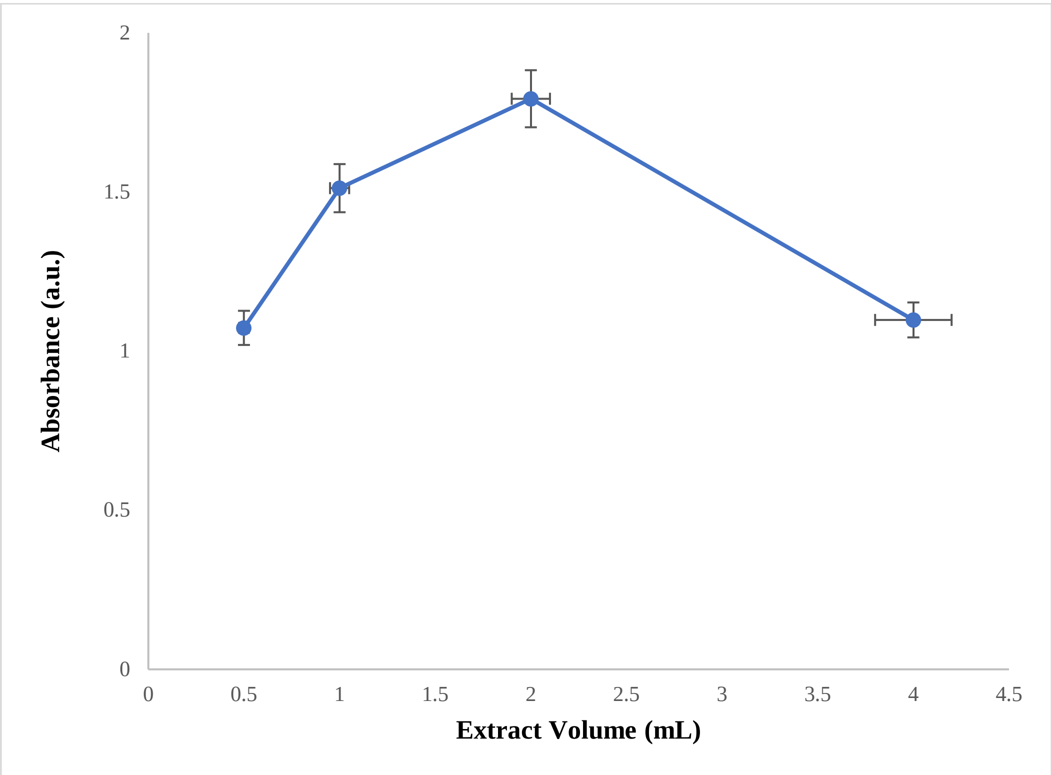

Figure 4. Extract volume optimization

When Figure 5 was examined, it was seen that the highest absorbance value was obtained when the extract volume was 2 mL. It has been observed that as the volume of extract used in nanoparticle synthesis is increased, the amount of silver nanoparticles obtained increases. Synthesis efficiency reached its maximum when the extract volume was 2 mL. If the extract volume continued to be increased, a decrease in the reaction efficiency was observed. After the extract volume was optimized, the reaction time optimization step was started. The mixture prepared using 1 mL of 100 mM $AgNO_3$, 2 mL of extract and 47 mL of pure water was subjected to magnetic stirring for periods ranging from 5 to 70 minutes. The amount of AgNP formed during the reaction was monitored with a UV-Vis spectrophotometer. The graph obtained in the reaction time optimization step is shown in Figure 5.

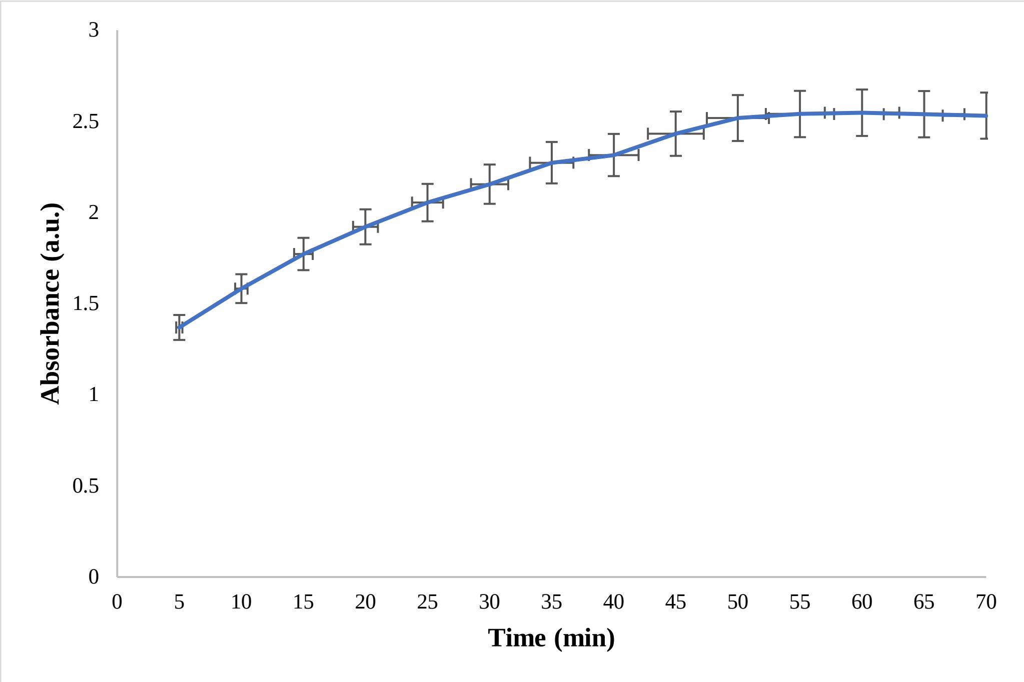

Figure 5. Reaction time optimization

When Figure 6 is examined, it was seen that the highest absorbance value was obtained when the mixing time was 60 minutes. In the step of optimizing the time in nanoparticle synthesis, it was observed that the reaction efficiency increased with time and the efficiency reached its maximum when the time was 60 minutes. It was understood that after the 60th minute, the reaction efficiency started to decrease. In the light of this information, the silver nanoparticles used in our study were synthesized under determined optimum conditions. During silver nanoparticle synthesis, the change between the 0th minute and the 60th minute of the reaction is presented in Figure 6. Dimensional analysis of the nanomaterials synthesized within the scope of our study was performed with the Zeta Potential Measurement Device (Zetasizer).

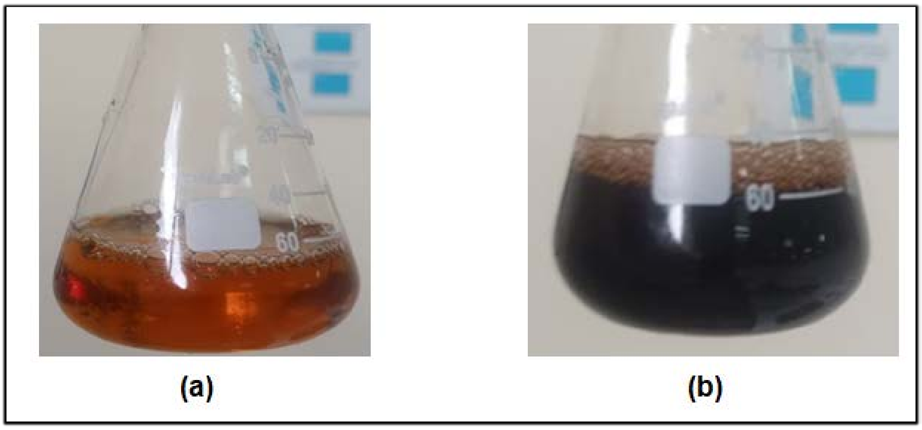

Figure 6. Color change in silver nanoparticle synthesis (a) 0. min. (b) 60th min.

2.5 Design of Pipette and Experimental Setup

Within the scope of the study carried out using some of these materials, a portable pipette containing four different filters was designed. The first filter was placed in the pipette as a coarse filter layer, the second filter as a layer containing activated carbon, the third filter as a layer containing magnetic nanomaterials, and the last filter as a layer containing silver nanoparticles (AgNP). Magnetic nanoparticle and silver nanoparticle were synthesized in the laboratory within the scope of our study. When water is drawn into the pipette placed in the water source, the drawn water is purified by passing through specifically selected filters to remove different pollutants. A schematic representation of the designed portable pipette is given in Figure 7.

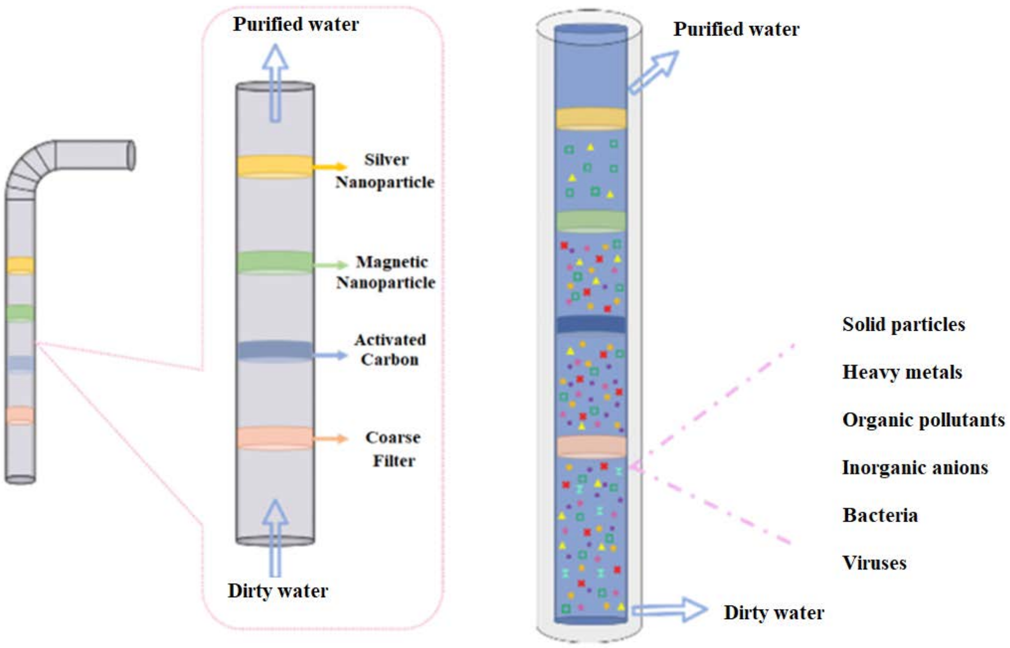

Figure 7. Schematic view of the pipette

The pipette used in our study is a commercial product made of hard plastic and sold in the market. First, a coarse filter was placed at the inlet of the pipette. Methyl parathion was used as analyte to determine the purification performance of our filter system. The concentration of methyl parathion used is 50 ppm. The suction force required to transfer liquid from the sample containing the analyte with the help of a pipette was provided by a vacuum pump. The experimental setup designed within the scope of our study is shown in Figure 8. The purification efficiency of the sample passed through the pipette was determined using UV-Vis Spectrophotometry. In measurements made with a UV-Vis spectrophotometer, the maximum wavelength of methyl parathion was found to be 273 nm.

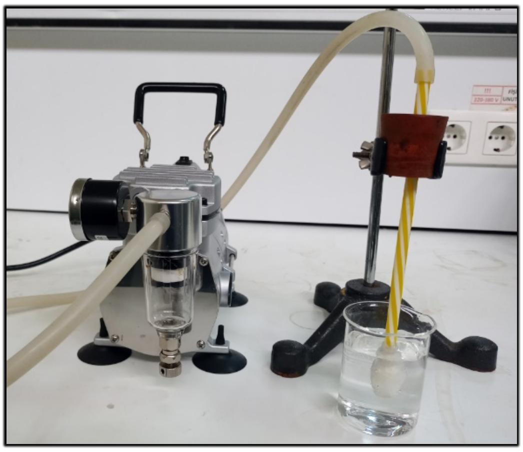

Figure 8. The experimental setup designed within the scope of our study

III. RESULTS AND DISCUSSIONS

In our study, an optimization study was first carried out on the amounts of filtration materials used in the pipette system we developed. For this purpose, the optimum amount of filtering layer was determined by placing the same amounts of activated carbon, magnetic nanoparticle and silver nitrate into the pipette in increasing amounts. The amounts of filtration material applied are shown in Table 1.

Table 1. Filtration material amounts

Silver Nanoparticle (AgNP) (mg)	Magnetic Nanoparticle (MNP) (mg)	Activated Carbon (mg)
1	1	1
2	2	2
4	4	4
6	6	6
8	8	8
10	10	10
12	12	12
14	14	14

The amount of chemicals to be used as the filtration layer in the pipette we developed has been optimized. Analyzes were carried out by increasing the amounts of silver nanoparticle, magnetic nanoparticle and activated carbon. 50 ppm methyl parathion was used as analyte in the analyses. The data obtained as a result of the measurements are presented in Table 2, and the graphical representation is presented in Figure 9. The percentage purification value was calculated according to the following equation: "%Purification: $[(A_0-A_P)/A_0]*100$" (A_0: The absorbance value of unpurified 50 ppm methyl parathion ; A_P: The absorbance value obtained after purification).

Table 2. %Purification

Silver Nanoparticle (mg)	Magnetic Nanoparticle (mg)	Activated Carbon (mg)	Absorbance	%Purification
1	1	1	0,243	39
2	2	2	0,201	50
4	4	4	0,2	50
6	6	6	0,163	59
8	8	8	0,156	61
10	10	10	0,14	65
12	12	12	0,147	63
14	14	14	0,148	63

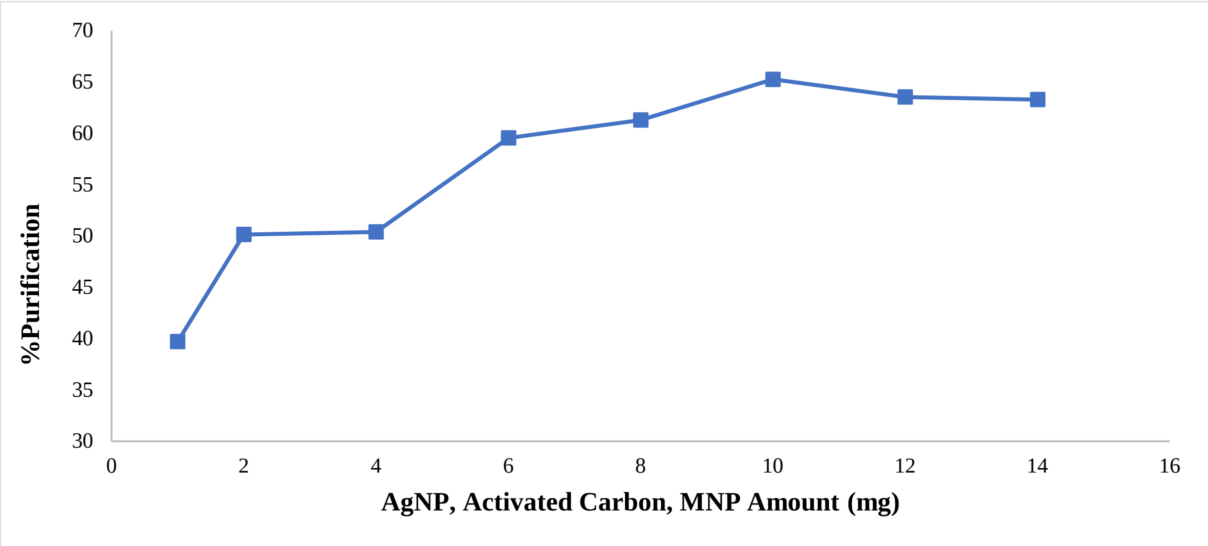

Figure 9. Effect of the amount of filtration layer on purification

When Figure 9 was examined, it was seen that the filtration layers used in the pipette we developed within the scope of our study should contain 10 mg of chemicals. After determining the optimum conditions of the filtration system in the pipette we developed, samples containing different concentrations of methyl parathion were passed through the pipette system and the change in purification efficiency was observed depending on the changing concentration. The absorbance values of methyl parathion standard solutions measured on the Uv-Vis Spectrophotometer are shown in Table 3.

Table 3. Absorbance values of methyl parathion standards.

Methyl Parathion (ppm)	Absorbance (Abs)
5	0,132
10	0,164
20	0,222
30	0,292
50	0,403

Methyl parathion samples with different concentrations were passed through the pipette system we developed and absorbance measurements were made again. The absorbance values and % purification amounts obtained as a result of the analyzes are shown in Table 4.

Table 4. Absorbance and %Purification values after filtration.

Methyl Parathion (ppm)	Absorbance (Abs)	%Purification
5	0,048	63
10	0,061	62
20	0,081	63
30	0,103	64
50	0,14	65

When Table 4 is examined, it was seen that the purification percentages of methyl parathion samples with different concentrations vary between 62% and 65%. These values are quite promising. The pipette system with filtration layers that we developed within the scope of our study is not significantly affected by the concentration of the analyte and can achieve a purification of around 65%. While calculating the percentage purification value, measurements made with the purified sample passing through four different adsorption layers in the pipette were used. It is considered that the chemical interaction of methyl parathion with both activated carbon and magnetic nanoparticles forms the basis of purification. Purification efficiency in the purification of analytes with increasing concentrations was found to be between 63 percent and 65 percent. It is seen that there is no significant change in percent purification with increasing concentration. This result reveals that the purification pipette we developed in our study can purify around 65 percent without being significantly affected by the analyte concentration.

IV. CONCLUSIONS

Within the scope of our study, a pipette was designed to be used in converting water samples obtained from different sources into drinkable water. Four types of filtration layers were used in the pipette to eliminate different sources of pollution. These filtration layers are coarse filter, activated carbon, magnetic nanoparticle and silver nanoparticle. Activated carbon and coarse filter were commercially available. Magnetic nanoparticle and silver nanoparticle were synthesized within the scope of our study. A unique method was developed in silver nanoparticle synthesis and clove extract was used as a reducing chemical source in the step of obtaining nanoparticles by reducing silver nitrate. Optimization studies were carried out within the scope of the synthesis method of silver nanoparticle and optimum conditions for synthesis were determined. After all the filtration layers were obtained, the pipette design step was started. Optimization was made to determine the amounts of chemicals to be used in the pipette. As a result of optimization, the amount of chemicals to be used was determined as 10 mg. The suction force required to ensure liquid passage through the pipette was provided by the vacuum pump. After designing the experimental setup, analytical performance tests of our pipette started. In the analyses, methyl parathion, which is used as an insecticide chemical in agriculture and has highly toxic properties, was used as the analyte. Methyl parathion is a chemical that threatens living health, affects the nervous system, and poses a risk to drinking water as a result of mixing with underground sources and streams. In order to evaluate the purification performance of our pipette, methyl parathion solutions ranging from 5-50 ppm were prepared and passed through the pipette. Methyl parathion samples that were not exposed to purification and methyl parathion samples after purification were analyzed in UV-Vis Spectrophotometer and absorbance values were determined. A remarkable decrease in absorbance was observed in the samples passed through the pipette system. The % purification values of samples with different concentrations vary between 62% and 65%. This result is quite promising. The pipette system with filtration layers that we developed in our study is not significantly affected by the concentration of the analyte and can achieve a purification of around 65%.

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