Iraqi Journal of Science, 2026, Vol. 67, No. 1, pp: 96-110
DOI: 10.24996/ijs.2026.67.1.8

ISSN: 0067-2904

Using Different Kinds of Activated Carbon for Removing Some Pollutants from Tap Water and Well Water

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Received: 29/4/2024 Accepted: 16/1/2025 Published: 30/1/2026

Abstract

Removal of some physical, chemical and biological pollutants from tap water and well water using three different types of activated carbon has been investigated in this research. Water samples were collected from the local area and treated in a closed system(a one-step household filter system), and the turbidity, electrical conductivity, total dissolved solid, chloride, some heavy metals such as lead (Pb), copper (Cu), nickel (Ni) and chromium (Cr), nitrite (NO_2), nitrate (NO_3) and total plate count has been measured before and after treating of the three types of activated carbon (lignocellulose activated carbon (AC1), anthracite coal activated carbon (AC2) and commercial activated carbon (AC3) which it prepare by chemical activation of the carbonized material and then washed and dried. The results showed the high efficiency of activated carbon in removing turbidity compared to other pollutants where it was in tap water 3.59NTU before filtration then after being filtered using the three types of activated carbon AC1, AC2 and AC3 were 1.18NTU, 1.36NTU and 2.27NTU respectively. Furthermore, turbidity in the well water before being filtered was 5.92NTU, and after filtering with AC1, AC2 and AC3 was 1.14NTU, 0.1 NTU and 2.4NTU, respectively. However, it is different in efficiency according to the type of activated carbon and the pollutant type since AC1 has a high efficiency to reduce Pb, and Cu, among others, where it declines from 0.054 ppm, 0.085ppm to 0.042ppm, 0.005ppm respectively for well water. AC3 was effective in lowering Cl, Ni, and Cr and reducing bacterial contamination where it was 283.3mg/l, 0.025ppm, 0.035ppm and 36cell/ml before filtering and 278.6mg/l, 0.011ppm, 0.015 and 27 cell/ml after filtering well water. AC2, which was more effective in adsorption of NH3 from 2.8mg/l to 1.2mg/l in tap water. Each type of activated carbon has shown quite good effects on a particular pollutant making it crucial to determine their application suitably. Although anthracite and animal base activated carbon is rarely used in water treatment, it exhibits quite good results in reducing some pollutants. In general, the adsorption capacity depends on the initial concentration of the sample, agitation speed and contact time.

Keywords: activated carbon, adsorption, pollutants, tap water and well water.

استخدام انواع مختلفة من الفحم المنشط لازالة بعض الملوثات من مياه الحنفية و مياه البئر

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الخلاصة

تم دراسه ازاله بعض الملوثات الفيزيائية و الكيميائية و البيولوجية من مياه البئر و مياه الصنبور. جمعت عينات المياه محلياً وعولجت في نظام مغلق. قيست الكدرة و التوصيلية الكهربائية و المواد الصلبة الذائبة و الكلور و بعض المواد الثقيلة مثل الرصاص و النحاس و النيكل و الكروم و النترات و النتريت و العد الكلي لاطباق قبل و بعد المعالجة باستخدام ثلاث انواع من الفحم المنشط (الليكنوسيليوزي و فحم الانثراسايت و الفحم المنشط التجاري) التي حُضرت من مواد متوفرة و تكلفه انتاجية قليلة لتحضير فحم منشط فعال اقتصادياً و صحياً. اظهرت النتائج ان الفحم المنشط ذو كفاءة عالية في ازاله الكدرة و بعض العناصر الثقيلة بالمقارنه مع باقي الملوثات. تعتمد كفاءة الازالة على نوع الفحم المنشط و نوع الملوث، حيث امتلك الفحم المنشط الليكنوسيليلوزي كفاءة عالية في تقليل الكدرة ، التوصيلية الكهربائية، الرصاص و النحاس بشكل افضل من باقي الملوثات , بينما اظهر الفحم المنشط التجاري كفاءة في تقليل الكلور, النيكل , الكروميوم, و المحتوى البكتيري, اكبر من فحم الانثراسايت حيث كان الاثاني اكثر كفاءة في امتزاز الامونيا. تعتمد كفاءة الامتزاز على التركيز الابتدائي للعينه, سرعه التفاعل و وقت الاحتكاك.

1. Introduction

Water is the most important natural resource that is necessary for the survival of humans and living organisms [1]. Therefore, total body water of humans in adults represents 50-70%; this water is distributed between intercellular fluid (65%) and extracellular fluid (35%). However total water in the human body varies depending on age, gender, health and weight. Most organs in the human body are composed mostly of water; for example, the brain is made up of 95% water, blood is 82% water, lung is 90% water, and nervous system cells contain 85% water [2]. Therefore, the daily water needed intake is 3.7L for adult male and 2.7L for adult female to meet the demands of the large majority of water [3]. Fresh water on earth represents 2% of the available surface water and groundwater; about 0.36% of it is set up in the form of groundwater [4]. Groundwater is the most natural source of valuable and important for life. It has become a vital source for several uses [5]. People have long believed that groundwater is pure in general and safe to drink, but it can also be easily polluted by different sources of pollutants. Some of these pollutants can be very toxic and difficult to recognize [1]. The contamination of water by agricultural, industrial and urban wastewater affects the life of many organisms, whether they are aqueous or mankind, as well as affects soil fertility [6].

Water treatment is the process of eliminating the most harmful substance that is present in the water, whether it is a chemical, physical or biological pollutant. It is an essential process before supply to consumption to create a sustainable life [7]. There were several methods for treating water that had been used across the century to enhance the odor, taste and quality of drinking water; some used filtration by wick siphon, algae and sedimentation until they discovered new technologies that involved disinfection using chlorine, ozone and other use of ion exchange for cation and anion removal, reverse osmosis (RO), micro-filtration (MF) and ultra-filtration (UF) [8].

Activated carbon is a carbonaceous material that can be produced from several organic raw materials such as walnut shells [9], orange peel [10], coconut shells, coal, wood chips, and animal bones [11]. It also can be produced from natural coal, such as anthracite [1]. The produced activated carbon is characterized by a large surface area, high porosity, large physiochemical stability and great surface reactivity, making it the most efficient adsorbent [12]. Activated carbon can be classified based on its physical properties as granular, powder, spherical beads, shaped pellets, cloths and fibers [13]. The preparation of activated carbon consists of two steps: carbonization of the raw materials and activation [14]; the activation can also be physical or chemical. The physical activation involves high temperature and an activating agent such as steam, carbon dioxide, air or their mixture. In contrast, the chemical activation is impregnation in one of the activation agents such as $ZnCl_2$, H_3PO_4, KOH, NaOH, H_2SO_4, HNO_3, $NaCO_3$, $AlCl_3$ and CH_3COOH [11]. Several factors affect the preparation of high-quality activated carbon, such as activation temperature, impregnation ratio and activation time [15]. Adsorption of surface active agent on metals from organic or aqueous solutions can sometimes be difficult because it can affect all constituents of the system, including solids, solvents, and solutes [16]. With regard to controlling water contamination activated carbon is the most utilized sorbent to eliminate different types of contaminants, such as pharmaceuticals, [17], dyes[18], pesticides and heavy metals, among other adsorbents [19].

Different raw materials and different preparation methods have been investigated in the preparation of activated carbon, each of which has a particular application. In this study provides a comparison between activated carbon prepared from natural coal, plant base and animal base activated carbon in overall water treatment, since anthracite has shown quite good efficiency as a multi-filter with sand grant, magnetite, and quantize sand in reducing NO_X and ammonia in water[20] in addition to adsorbing some gaseous pollutant such as CH_4 and CO_2 [21] in the other hand wood base activated carbon has shown a decrease in organic pollutant, dyes and some bacteria such as *E.coli* [22] Finally, commercial activated carbon produced from animal organic tissue such as its bones, hair, feather, hooves or even the entire body more effective in chromium adsorbent [23]. The main goal of this research is to evaluate the effectiveness of three various types of activated carbon in removing physical, chemical, and biological pollutants from various water sources and determine the best type.

2. Experimental part

2.1 Instruments and Devices

Turbidity meter from Lovibond Company, UV- spectrophotometer from Shemadzu, WTW Cond 720 laboratory conductivity meter, and atomic adsorption spectrometer from nov AA 400 P. were used in this study.

2.2 Materials

Potassium hydroxide pellets KOH from SDFCL Company, HCl from Thomas Baker, distilled water, anthracite coal import from China, commercial activated carbon from APC Company, and wood base coal from a local market.

2.3 Methods

Three types of adsorbent were obtained in this study: lignocellulose activated carbon (AC1), Anthracite coal activated carbon (AC2), and commercial activated carbon AC3). The AC1 and AC2 were prepared using wood base coal and anthracite coal, respectively, by chemical activation, which is done by impregnation of the carbonized materials with KOH for 24 hours at room temperature, then washed with HCl and distilled then dried before using as adsorbent this method was performed as stated by Abd Rashid *et al*. [24] and M. Chaied [25], with some modification. Soaking of metals in carbonaceous materials qualifies the gasification characteristics and changes the porous structure of the final carbon product[26]. The preparation of activated carbon from lignocellulose materials was performed at a library scale at limited operating situation. The porosity of the produced activated carbon was measured using a scanning electron microscope (SEM).

The adsorption was studied under the closed system by passing water through the three types of activated carbon and measuring water's physical, chemical and biological properties before and after treatment with activated carbon. Turbidity (TUR) was measured using a turbidity meter, for total dissolved solid TDS, and electrical conductivity EC WTW Cond 720 laboratory conductivity meter was used for these tests. Chloride (Cl) has been measured by titration 25ml from the sample and 1ml of potassium dichromate against silver nitrate ($AgNO_3$) to a reddish-brown ending point. The results have been calculated using the following formula:

$$Cl\ mg/l = \frac{(A-B)*N*35450}{\text{ml of sample}} \quad \text{.... (1)}$$

A is ml of $AgNO_3$ for the sample, B is ml of $AgNO_3$ for blank, and N is the normality of $AgNO_3$. NO_2 and NO_3 were measured using a UV- spectrophotometer. Heavy metals were measured using an atomic adsorption photometer.

3- Results and Discussion

In this study, the concentrations of some physical, chemical, and biological parameters of tap water and well water have been measured and compared with the World Health Organization (WHO) standards as shown below:

3-1 Physical parameters

3-1-1 Turbidity

Results in Figure 1 show the concentration of turbidity in tap water and well water before and after it is filtered with activated carbon. For tap water, the data were quite good, where it was 3.59NTU before filtration, then after being filtered using the three types of activated carbon AC1, AC2, AC3 were 1.18NTU, 1.36NTU, and 2.27NTU, respectively. Furthermore, for well water the turbidity of water before being filtered was 5.92NTU and after filtering using the three types of activated carbon as 1.14NTU, 0.1 NTU, and 2.4NTU, respectively. The results show a slight decrease in turbidity in water after filtering in the two sources of water. Turbidity in the water depends on the quantity of suspended solids present in the water; it could be silt, clay, non-living organic particles, organic or inorganic matter or even planktons or other microorganisms. In contrast, the acceptable level of turbidity in drinking water, according to WHO, is 5.00NTU (Table 1) [27].

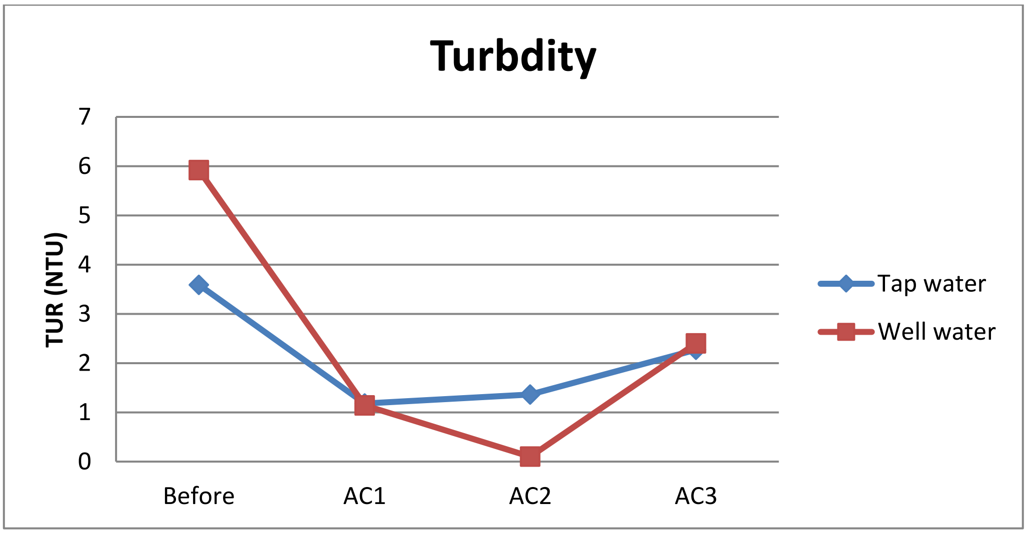

Figure 1: The concentration of turbidity in tap water and well water before and after filtering with lignocellulose activated carbon AC1 , Anthracite coal activated carbon AC2 and commercial activated carbon AC3

3-1-2 TDS and EC

The EC and TDS were measured before and after filtering with activated carbon. For TDS, as shown in Figur2. In tap water, the result before being filtered was 392.3 ppm and after filtering using the three types of activated carbon, 423.6 ppm, 405.3 ppm, and 404.3 ppm, respectively. Meanwhile, for well water, the result of TDS before being filtered was 1570.6 ppm, and after filtering using the three types of activated carbon, 1641ppm, 1562.3ppm, and 1572.3ppm respectively. Furthermore, for EC before filtering, it was 780.6 µS/cm and after filtering 878 µS/cm, 792.6 µS/cm, 793.3 µS/cm, respectively. In well water before filtering it was 2686.6 µS/cm and after filtering 2810 µS/cm, 2670 µS/cm, and 2686.6 µS/cm respectively, as shown in Figure 3. There are many standards that govern TDS and EC in water. In some cases, the interaction between chemicals and carbon increases the TDS and turbidity[28]. The desirable limit of TDS for health reasons is 500mg/L, and for EC, it should not rise above 1500. In general, a high concentration value of TDS in well water is not harmful to humans, but it could affect those who suffering from kidney and heart issues [27].

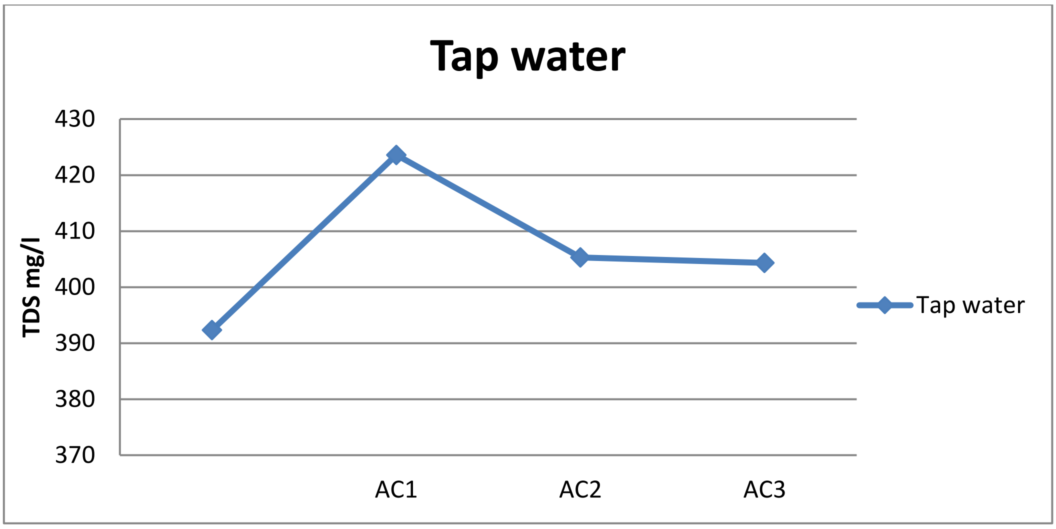

Figure 2 : Concentration of total dissolved solid TDS before and after filtering lignocellulose activated carbon AC1, Anthracite coal activated carbon AC2 and commercial activated carbon AC3 in tap water

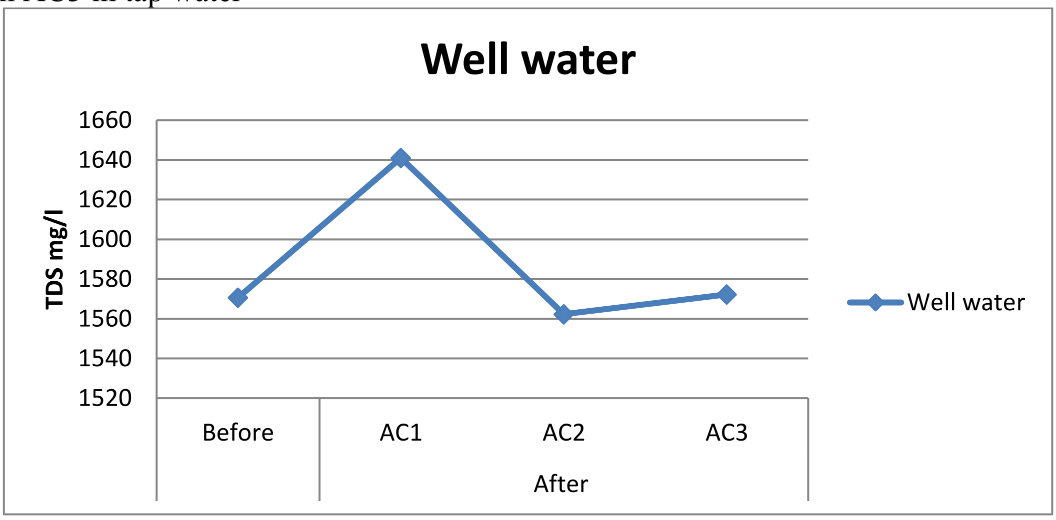

Figure 3: Concentration of total dissolved solid TDS before and after filtering lignocellulose activated carbon AC1, Anthracite coal activated carbon AC2 and commercial activated carbon AC3 in well water

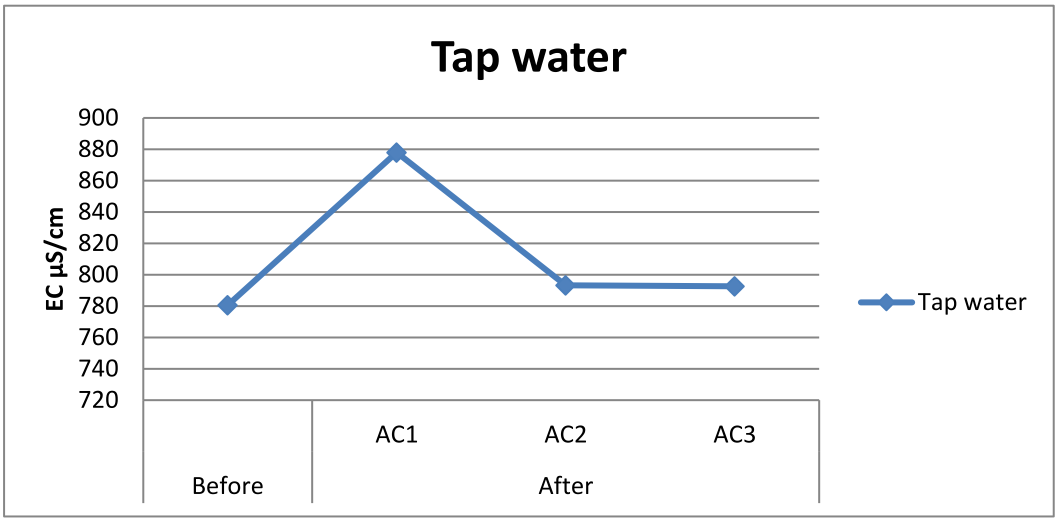

Figure 4: Concentration of electrical conductivity EC before and after filtering lignocellulose activated carbon AC1, Anthracite coal activated carbon AC2 and commercial activated carbon AC3 in tap water

3-2 Chemical parameters

3-2-1 Chloride

The mean value of chloride shows a different variant for the three types of activated carbon (Figure 4). For tap water, the concentration of chloride before filtering was 223.3mg/l, and after filtering with AC1, AC2, and AC3 was 225mg/l, 208.3mg/l, and 222mg/l, respectively. While the well water before filtering was 283.6mg/l, and after filtering with AC1, AC2, and AC3, it was 302.6mg/l, 278.6mg/l, and 282.3mg/l, respectively.AC2 and AC3 showed a pretty good adsorption for chloride as compared to AC1. In accordance with WHO standards, the concentration value of chloride should not rise above 250mg/l (Table 1)[27].

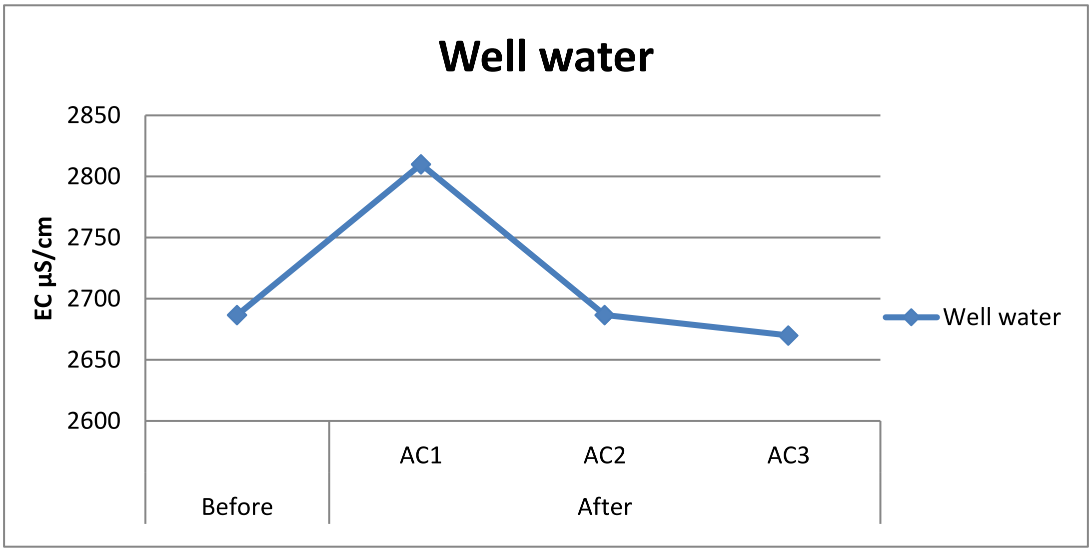

Figure 5: Concentration of electrical conductivity EC before and after filtering lignocellulose activated carbon AC1 , Anthracite coal activated carbon AC2 and commercial activated carbon AC3 in tap water

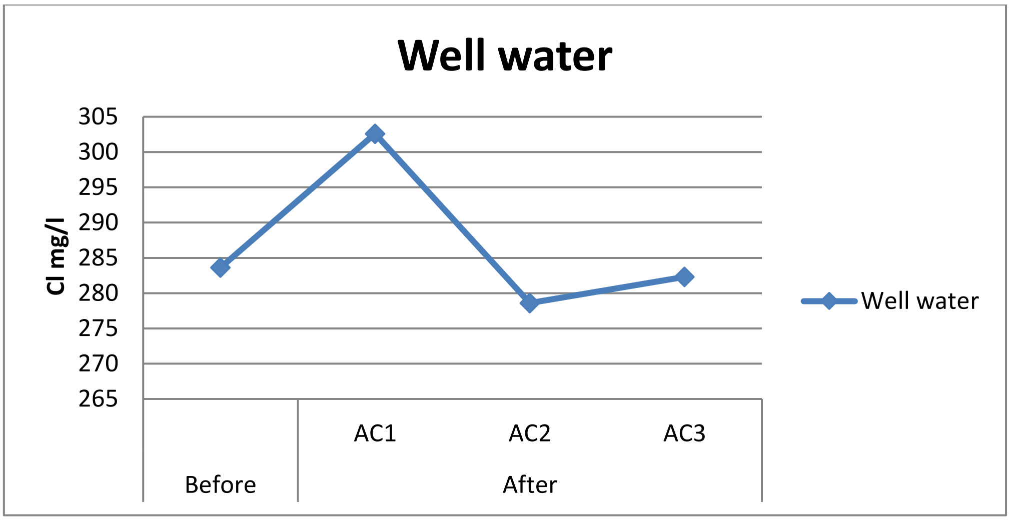

Figure 6: Concentration of chloride before and after filtering lignocellulose activated carbon AC1 , Anthracite coal activated carbon AC2 and commercial activated carbon AC3 in tap water

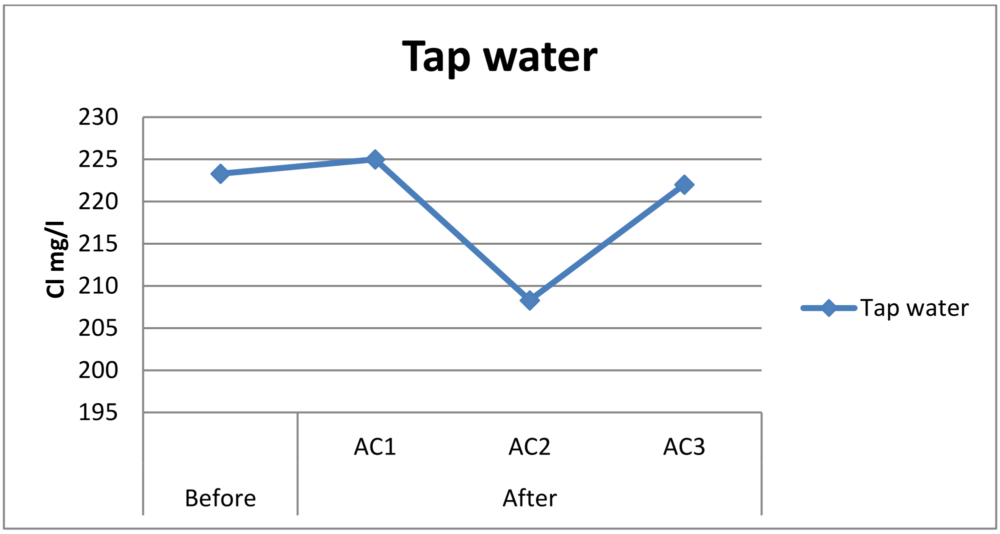

Figure 7: Concentration of chloride before and after filtering lignocellulose activated carbon AC1, Anthracite coal activated carbon AC2 and commercial activated carbon AC3 in well water

3-2-2 *Heavy metals*

Four types of heavy metals have been measured in this study, including Pb, Cu, Ni, and Cr, as shown in Figure 5. Tap water has not shown any concentration of heavy metals, which meets the WHO standard level. In contrast, it shows a good result in well water adsorption. It showed a decrease in Pb, Cu, Ni, and Cr concentration after it was filtered with the three types of activated carbon and because of the more active site of adsorption for these materials [29].

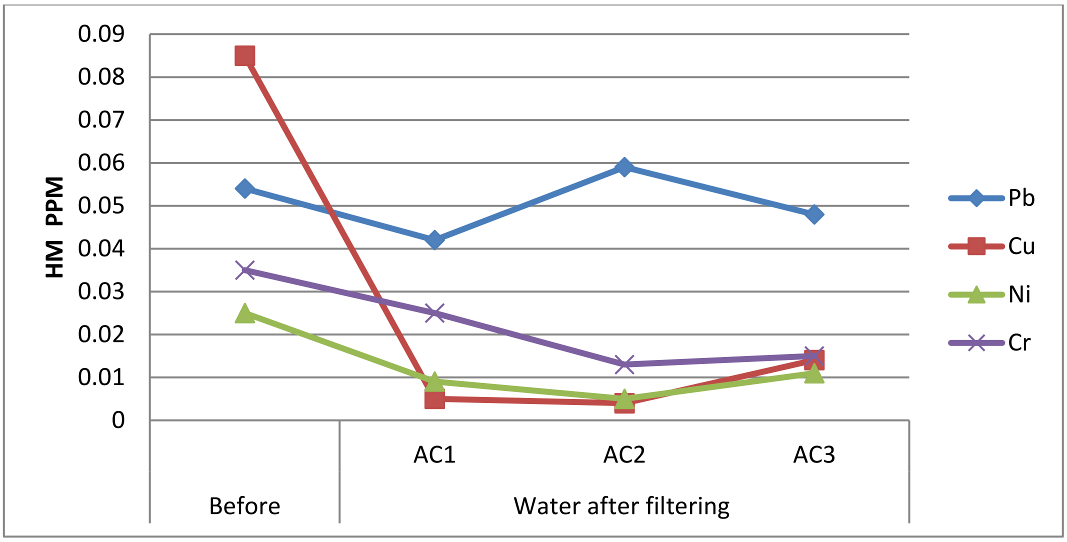

Figure 8: Concentration of heavy metals in well water

The pH also affects on the adsorption of heavy metals where hydrogen ion[H^+] in law pH compete with heavy metal ions, which have the same positive charge for the adsorption sites in activated carbon; therefore, the adsorption of heavy metal will decrease the optimal pH value for improving adsorption of heavy metal is ranging between 5 and 6 [30]. There are many reasons for the decrease in the adsorption of heavy metals, such as particulate matter and the interaction of water with microplastics. The last not only decreases adsorption but also increases some heavy metals [31].

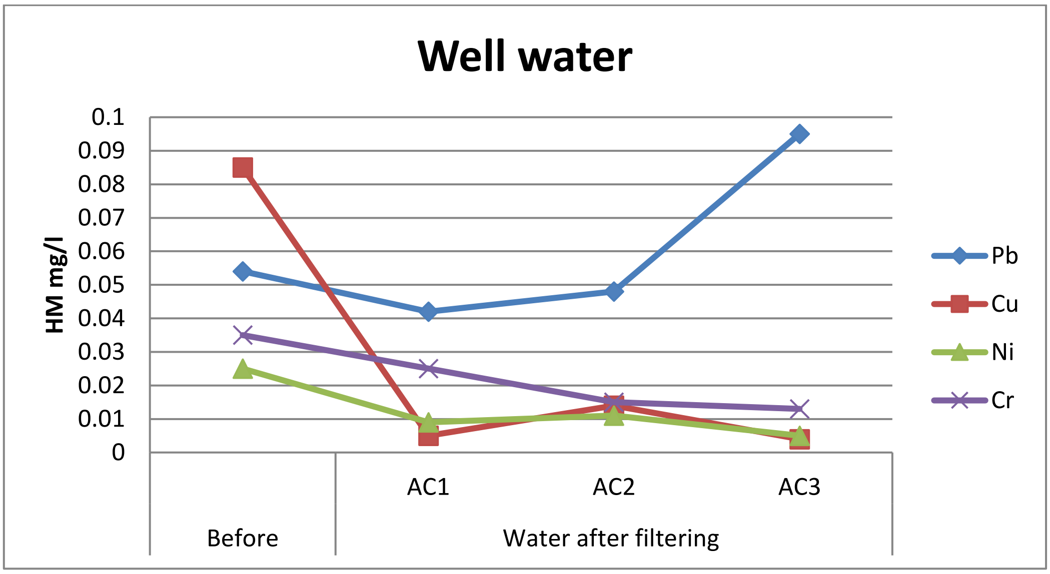

Figure 9: Concentration of nitrite NO_2, and nitrate NO_3 before and after filtering lignocelluloses activated carbon AC1 , Anthracite coal activated carbon AC2 and commercial activated carbon AC3 in tap water

Table 1: Parameters after filtering and drinking water standard in Iraqi slandered IQS[32] and WHO standard[33]

Parameters	After filtering						Iraqi standard for drinking water IQS	Water quality index WQI(world health organization WHO)
	Tap water			Well water				
	AC1	AC2	AC3	AC1	AC2	AC3		
TUR (NTU)	1.18	1.36	2.27	1.14	0.1	2.4	5	5
TDS (mg/l)	423.6	405.3	404.3	1641	1562.3	1572.3	1000	1000
Cl (mg/l)	225	208.3	222	302.6	278.6	282.3	350	250
Pb (mg/l)	0	0	0	0.042	0.059	0.048	0.01	0.01
Cu (mg/l)	0	0	0	0.005	0.004	0.014	1.0	2.0
Ni (mg/l)	0	0	0	0.009	0.005	0.011	0.02	
Cr (mg/l)	0	0	0	0.025	0.013	0.015	0.05	0.05
NO_2(mg/l)	5.07mg/l, /l,	4.57mg	4.64mg/l	36.1mg/l, /l and	36.7mg	36.6mg/l	3	3
NO_3 (mg/l)	6.76	6.2	6.1	48.23	49	49	50	50
NH_4 (mg/l)	0.9	0.9	1.2	0	0	0	0.5	0.5

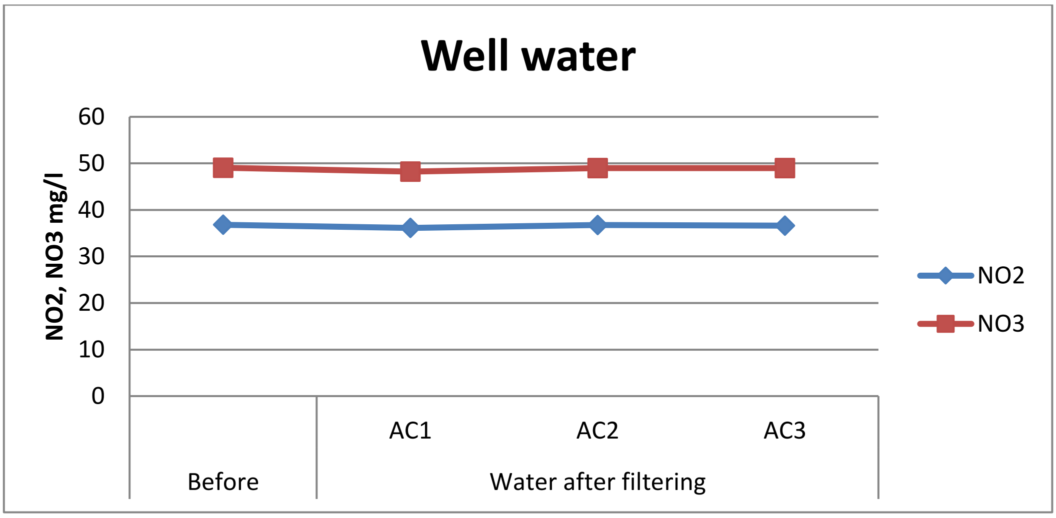

Figure 10 :Concentration of nitrite NO_2, and nitrate NO_3 before and after filtering lignocellulose activated carbon AC1 , Anthracite coal activated carbon AC2 and commercial activated carbon AC3 in well water

3-2-3 NO_2, NO_3

For nitrate and nitrite adsorption on activated carbon, as it shown in Figures 9 and 10, NO_2 in tap water before filtering was 4.13mg/l and after filtering with AC1, AC2, and AC3, it was 5.07mg/l,4.57mg/l, and 4.64mg/l respectively, as for well water, NO_2 before filtering was

36.8mg/l. After filtering with AC1, AC2, and AC3 it was 36.1mg/l, 36.7mg/l and 36.6mg/l, respectively. However, for NO_3 in tap water before filtering, it was 5.6mg/l, and after filtering with AC1, AC2, and AC3, it was 6.76mg/l, 6.2mg/l, and 6.1mg/l respectively, while well water before filtering was 49mg/l. After filtering with AC1, AC2, and AC3, it was 48.23mg/l, 49mg/l, and 49mg/l respectively. The adsorbents of NO_X on activated carbon by the chemical reaction between NO_X and the activation agent on the surface of the activated carbon [34]. The WHO maximum limit of nitrate is 50 mg/l in drinking water, as it shown in Table (1).

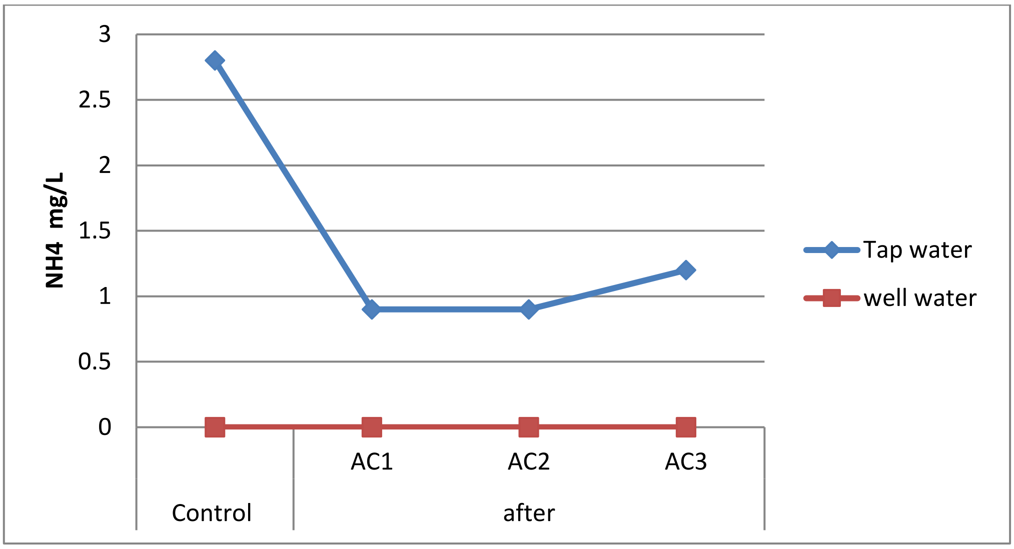

Figure 11: Concentration of ammonia NH_4 before and after filtering with AC1, AC2, AC3

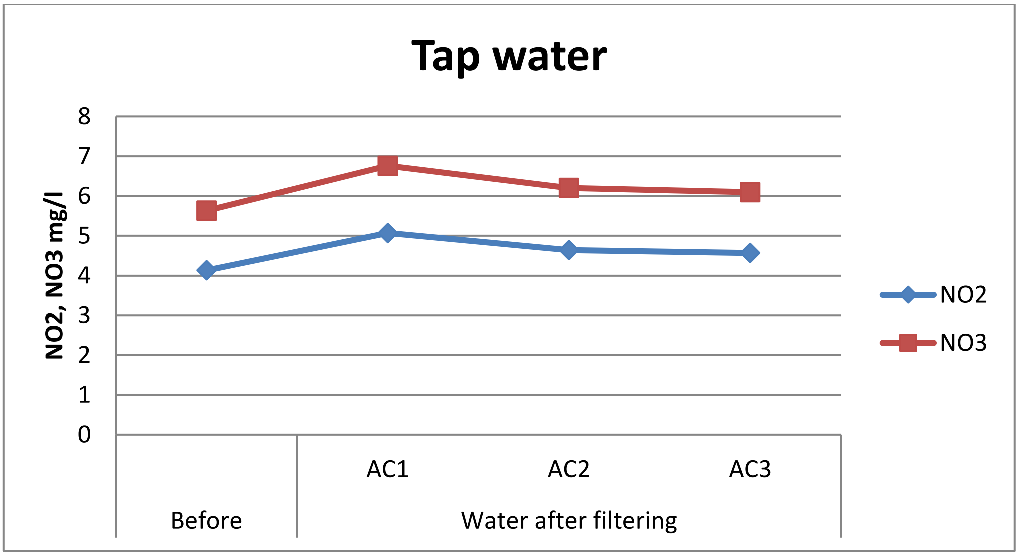

Figure 12: Total plate count of bacteria in tap water before and after filtering with AC1, AC2, and AC3

3-2-4 NH_4

The results demonstrated in Figure 11 for tap water, revealed there was a decrease in ammonia concentration after it was filtered where the mean value of NH_4 before filtering was 2.8 mg/l while after filtering with AC1, AC2, and AC3 was 0.9 mg/l, 0.9mg/l, and 1.2mg/l, respectively. Although, ammonia enters surface water from landfills, industrial effluents, and diffused pollutants from fertilizers and pesticides, it also enters tap water from damaged pipes

[5, 35]. Ammonias found in groundwater naturally by anaerobic decomposition of organic maters [36].In contrast, well water does not contain ammonia.

3-3 Biological parameters

Total plate count (TPC) has been measured for both tap water and well water before and after treatment, and the data showed quite good results for tap water. The mean value of TPC before treatment was approximately 10 cell/ml, while after filtering with AC1, AC2, and AC3, was 1 cell/ml, 3 cell/ml, and 0 cell/ml respectively. While for well water, before filtering, it was 36 cell/ml, and after filtering using AC1, AC2, and AC3, it was 35 cell/ml, 30 cell/ml, and 27 cell/ml. The potential of some bacteria to diffuse through water causes a series of healthcare-related accidents [37] so it is important to pay attention to finding a method that could reduce it. The removal of microbiology depends on the amount of activated carbon that has been used, its pore size, and the amount of water that has been filtered.

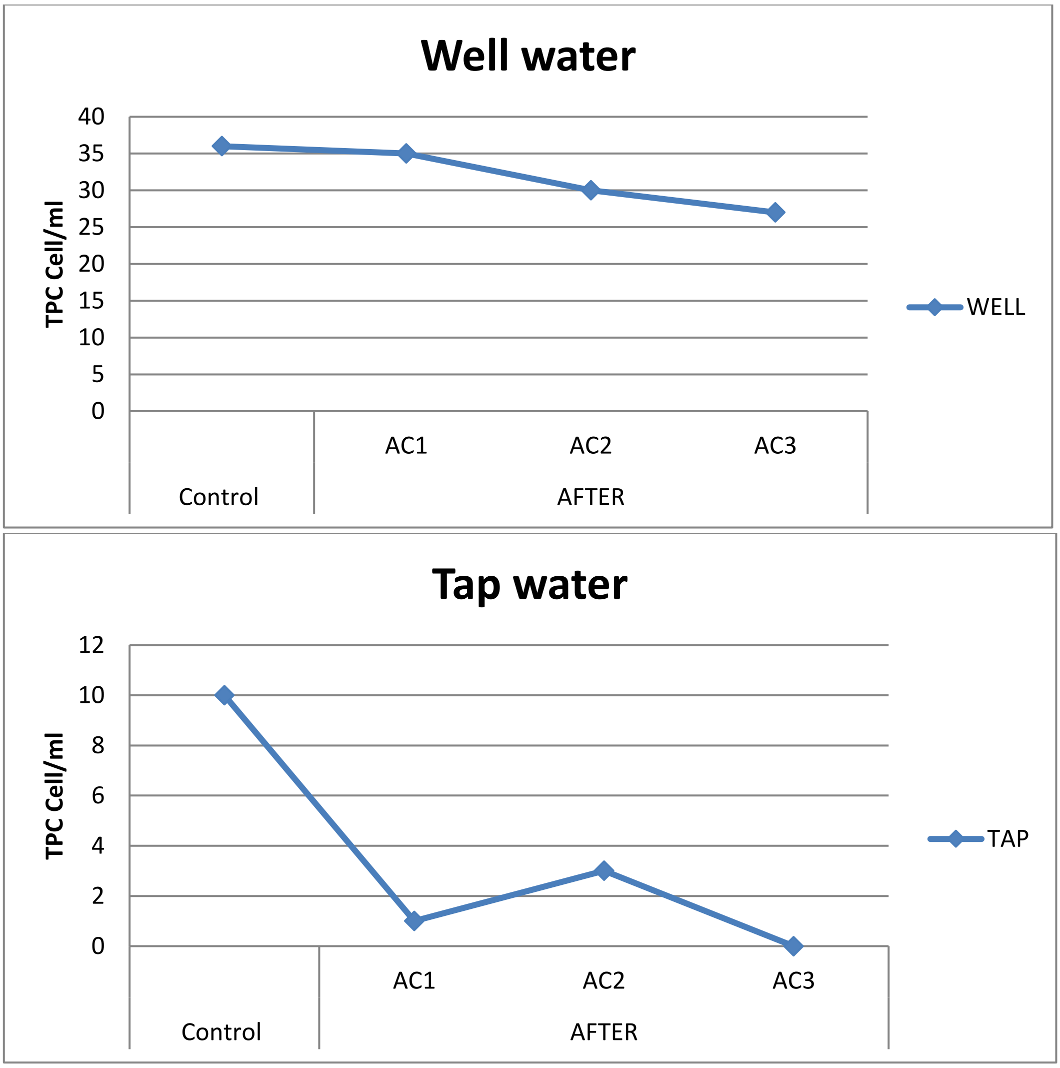

Figure 13: Total plate count of bacteria in well water before and after filtering with AC1, AC2, and AC3

SEM analyses

SEM analyses of the three types of activated carbon are presented in Figure 14. Where the pores of AC1 before activation were 34.8µm , and 152.7µm (Figure 14,a) and after activation the pore area was 13.2µm, and 188 µm (Figure 14,b) for after treating water it was 5.8µm, and 27.6 µm with some impurities as it noted in Figure 1,c. AC3 has a smaller porosity than AC1. (Figure 14,d,e) showed the porosity of AC3 before treating water, which was 0.829 µm in size, and after using it in treating water, was 2.206µm, and 1.07µm, as observed in Figure14,f. However, AC2 has not been organized or observed as porous (Figure 14, g,h,i), which shows AC2 before and after activation and filtration, respectively. The main advantage of measuring porosity is to detect where each type of activated carbon can be applied. Therefore, activated carbon with microporous less than 2nm pore size is more effective in gas adsorption (the treatment of air pollution). In contrast, activated carbon with mesoporous 2–50 nm pore size [38] is essential in transporting fluids in to the smallest porous to be adsorbed, so it is more efficient in water treatment [39].

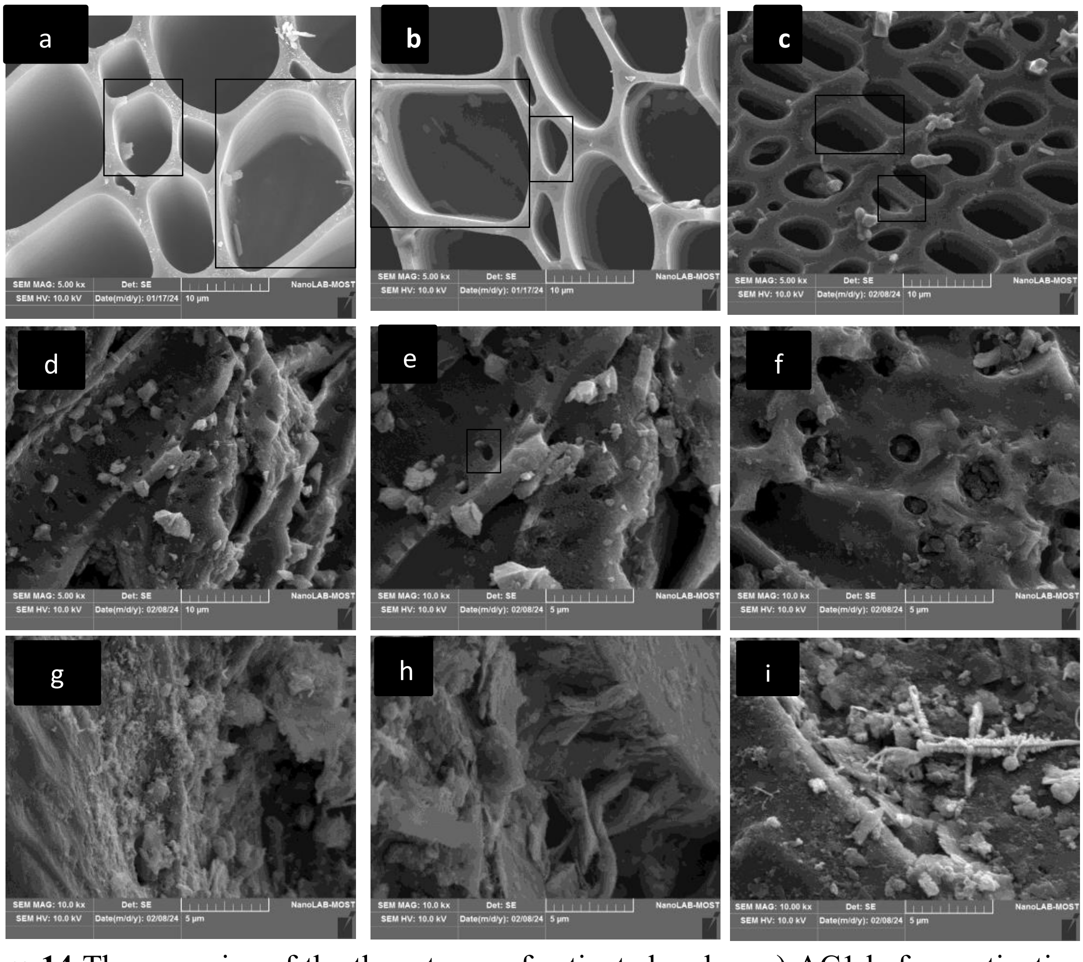

Figure 14 The pore size of the three types of activated carbon a) AC1 before activation as a raw coal b) AC1 after chemical activation c) AC1 after water filtering d,e)AC3 before water filtering f) AC3 after water filtering g) AC2 before activation as a raw anthracite coal h) AC2 after chemical activation i) after water filtering.

4- Conclusion

Although the three types of activated carbon showed a higher efficiency in removing turbidity and heavy metals than other pollutants, it is different from one type of activated carbon to another and from pollutant to another. It has been found that AC1 was better in reducing EC, Pb, and Cu compared to AC2 and AC3, which were better in reducing Cl, Ni, and Cr and reducing bacterial contamination. As for NO_2, NO_3 remain constant before and after filtering. Also, the efficiency removing of any pollutant by any type of activated carbon is different in tap water and well water, and that depends on the initial concentration of the pollutant and the amount of sample. In addition, it takes plenty of time to show a high efficiency. In general, AC2 was the best type among others in both adsorption capacity and cost of preparation and modification; since it does not need a carbonization step and readily found as a natural source, it is preferred to add it as a step in water treatment units, since it lighter in weight and more suitable in a household system with post filtration to reduce total solid TS.

Conflict of Interest: "The authors declare that they have no conflicts of interest.”

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