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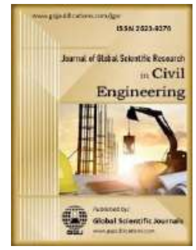

Performance Evaluation of Different Types of Sawdust in Reducing Water Pollution

Taha A. Al-Tayyar[1], Moath Abdullah Najm[2]

[1]Environmental Research Center, Mosul University, Mosul, Iraq.
[2]College of Agriculture and Forestry, Mosul University, Mosul, Iraq.

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ABSTRACT

Sawdust is a natural organic material. The chemical composition of sawdust consists from 28% of cellulose and 10% of lignin, as well as contains many effective functional groups of low molecular weights such as hydroxyl groups, carboxyl and phenol in its composition. According to the size, sawdust is classified into four sizes, such as dry sawdust or sawdust treated physically by washing and then drying at a temperature of 80°C, or using sawdust in its normal state as in woodworking plants and at different treatment times. Concerning raw water samples for treatment by sawdust, they were collected from several sources of surface water from the Tigris River, Al-Khosur River and from well water as a source of groundwater due to the different water quality for each. Sawdust has proven, to absorb salts and reduce their concentrations in polluted water. Reduction concentration of dissolved salts of the water treated with sawdust from (1910 ppm) to (1603ppm) with a removal rate of (16.07%) for sawdust in its normal condition without washing, and the removal percentage increased to (24.18%) for washed sawdust and dried, after the concentration of dissolved salts decreased to (1448 ppm).The reduction in electrical conductivity in µmohs /cm2 were also observed to have the same percentages. Total hardness and their main salts as Calcium and Magnesium cations, in addition to Sulfate and Carbonate, Bicarbonate as anions were also decreased to improve water quality. Also pH values for treated waters were approximating normal values of about 7.0. The results showed that the fine sawdust adsorption increased by 2.17 times over the coarse one.

1. Introduction

Wood is a natural organic material. It can mold and take different states during its growth. The source of wood is plants and trees such as forest trees, It consists mainly of molecular materials, which are (saccharides) as cellulose and half-cellulose, as well as to lignin or lignin. Cellulose constitutes approximately 28% and quinine 10% of the chemical composition of wood. Besides, wood contains many effective functional groups of low molecular weight from mineral and organic materials like hydroxyl groups, carboxyl and phenol in its composition [14]. For these components, wood products as leaves, fruits, seeds and sawdust contains variety of active constituents that have wide spectrum of impacts

Corresponding author:
E-mail addresses: ta_tayyar@uomosul.edu.iq (Taha), moathalhajjar@uomosul.edu.iq (Moath)
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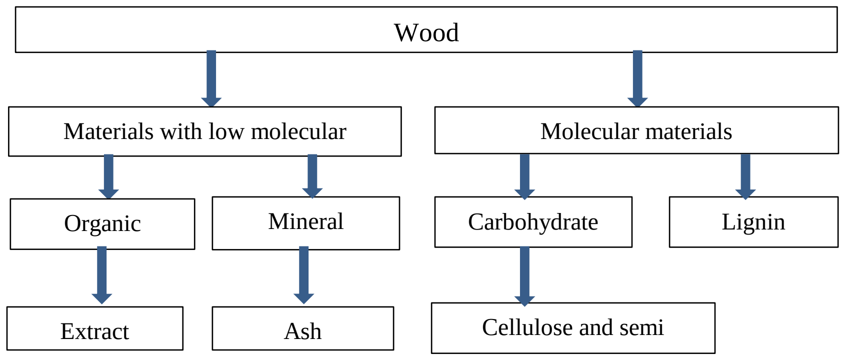
[8]. Scheme (1) shows the main components of wood.



Scheme 1 :The main composition of wood

Sawdust is an unintended product of several wood applications, which most carpentry company owners desire to dispose of as solid waste with no economic value. Large quantities of sawdust are available in mechanical carpentry workshops, posing a difficulty in the disposal process. However, modern environmental protection concepts, which prioritize sustainable development as one of their most important applications and principles, emphasize no waste or zero waste streams. This necessitates finding beneficial uses for any material, whether it is raw material or a by-product of various activities.

Sawdust wastes witnessed a variety of uses. Sawdust for instance is used in treating waste water and purifying it of minerals and some organic pollutants. In addition to utilization in heating as well as laying the floors of chicken fields and stables. When natural or un-industrial materials are wastes, their useful uses are the way to give waste materials valorization [21]. "Sawdust" was using to cleanse industrial water from dyes, such as red, green, and blue acidic dyes. She found that "sawdust" could absorb the dyes at rates of 82, 70, and 86 mg/g respectively as the sawdust contains a high percentage of cellulose, which plays a role in absorbing chemical dyes [2]. On the other hand, [20] used fine eucalyptus sawdust as activated carbon to reduce COD and TDS concentration of dairy waste water. Also, the seedling of Eucalyptus utilized as absorption materials of heavy minerals from polluted soil and get rids the soil from pollutants [5].

Safe and suitable water is not available at the required time and place. So, if invested optimally, it will reduce the risks of decreased quantities and undesirable qualities of water in which constitute a threat to the environment in the region [25].

Adsorption is suitable treatment of water to release pollutant as dissolved salts. When local materials is used as adsorbents, other benefits will come true. As; low cost, cheaper treatment, more flexible, more effective; has greater simplicity of design, ease of operation, and insensitivity to toxic pollutants [7]. The other benefit utilizing of sawdust is using as a combined medium filter cake which is suitable for cultivating. Also, sawdust and calcium carbonate was utilized as the combination of both waste products in vegetation growth and fruiting body formation [15].

This research aims to study the ability of white sawdust in various cases in terms of physical treatment and the size of sawdust granules to adsorb dissolved solids, hardness salts to reduce their concentrations in the raw water used in the city of Mosul with different concentrations in surface water and groundwater wells.

The Role Of Sawdust In Removing Chemical Pollutants

Many challenges are faced in using water. Apart from the scarcity of water, there are many other challenges in providing a safe, adequate and reliable water supply in many parts of the world [22].

Many technologies are in practice to treat water and Adsorption is one of them. Scientific research's have been interested in studying the adsorption process on the surfaces of adsorbent materials, as this process being inexpensive. It was shown by [19] that barley straw, human hair, sawdust are natural materials that have the ability of adsorption.

Tertiary treatment of refinery waste water disposal which containing quantities of hydrocarbons pollutants was developed by using adsorption techniques process benefit with activated carbon [23]. This technique is useful for reducing the concentrations of pollutants that cannot be released by the usual methods, but it requires advanced techniques and at high economic and technical cost. The persistence of dissolved compounds in water and their entry into the food chain to reach humans will have significant negative health and environmental impacts [17]. Therefore polluted water must be treated accurately before reuse . Sawdust can be chemically modified by adding cationic to be used as a water treatment material for the removal of anions as nitrate, vanadate and other complex contaminators [12]. Also, [1] succeeded in utilizing the adsorption mechanism in release the antibiotic solutions from water and waste water by employing other bio friendly materials as algal biomass.

2. Materials and Methods

White sawdust was used after collecting it from carpentry workshops in Mosul. Sorted and classified accorded to its size using standard sieves (1.0, 2.0, 4.0, 10.0 mm). This classification was done to classify the sawdust granules for the purpose of studying the effect of the diameter on improving water quality and choosing the best effective size in the adsorption process.

For all samples, (10 g) of the remaining dry sawdust was weighed on each sieve, Classification was made according to size into three types : fine sawdust (1-2 mm), intermediate sized (2-4 mm), coarse sawdust, greater than 4 mm (4-10 mm) > . Sizes smaller than (1 mm) granules were excluded due to the small size eliminated and other types was taken for subsequent experiments, Figure (1) shows the shape and size of the sawdust used.

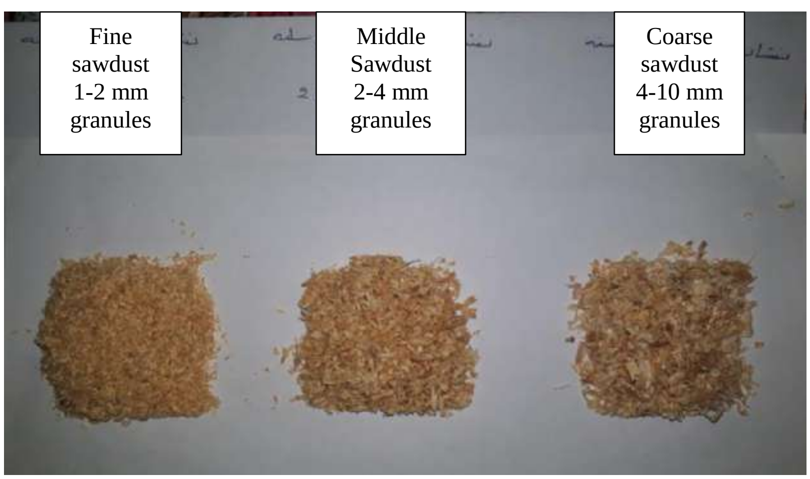


FIGURE 1 : The shape and size of the sawdust used

Samples of sawdust were used directly without washing to study their ability to adsorb dissolved salts. Also, taken the same amount of dry sawdust was washed with distilled water to get rid of the dissolved impurities, by placing it in a glass beaker, according to the researchers [18]. Distilled water is added with shaking for 30 minutes and for several times (three to four washings) until the electrical conductivity of the washing water is close to that of the distilled water used for washing, filtered and placed in the electric oven at 80 °C for 24 hours to dry it and get rid of the volatile organic matter, as the researchers [6]. The amount of impurities and very fine sawdust that were removed by washing process amounted to 0.03 g/g of sawdust, which is equivalent to 3% of the weight of sawdust.

Fresh water is not available in their quality and quantity. Human activities, climates change, global warming and dissertation are some influential agents on water[4]. Also, ground water is a reflection of geological formation of the water basin aquifer , therefore, quality of well water may be differ than others. In any case, ground water will have salinity higher than surface water [16]. Mosul city is a realistic example of that. Sampling water were taken from Tigris river, Al-Khosur River and arterial wells from Al- Wahda and Al-Kindy regions with different concentrations of dissolved salts. Shaking for different times with different cases of sawdust, washing and un-washing sawdust for different granules. Then measuring the pH, the amount of dissolved salts electrical conductivity, total hardness and their ions.

Figure (2) shows the locations of sampling points of surface water from Tigris River, Al-Khosur River and the groundwater from artesian wells in the Al-Wahda neighborhood area which is close to the Tigris River and from the Al-Kindy neighborhood that is higher than the level of the Tigris River on the aerial map of the city of Mosul.

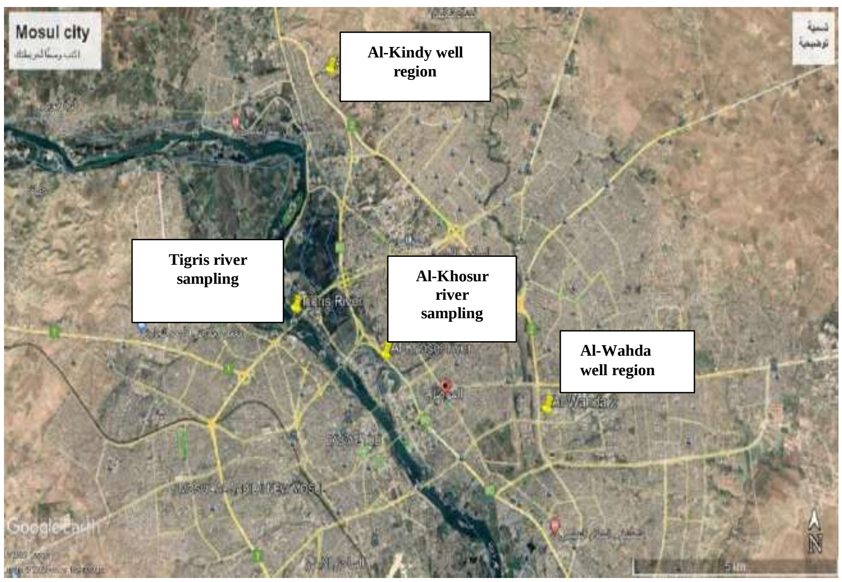


FIGURE 2 : An aerial photo of the city of Mosul, showing the locations of taking water samples

3. Results and Discussion

Sawdust properties were measured in the laboratories of the University of Mosul**.** Table (1) represents the physical properties of white sawdust. It shows the great difference in normal density, compacted density and wet density due to the sawdust's ability to compress, in addition to its ability to absorb and adsorb.

TABLE 1 Physical properties of sawdust

Parameters	Unit	Value
Specific weight	kg/m^3	0.6-0.62
Adsorption	%	50
Dry density	kg/m^3	140
Compacted Density	kg/m^3	210
Wet Density	kg/m^3	775

250 mL of high salinity groundwater from the Al-Kindy neighborhood well was added to (10 grams) of natural sawdust. The total dissolved salts (TDS) of well water reached (1910 ppm). Treated well water by mixing and shaking with sawdust at different times (5, 10, 15 minutes), the ability of sawdust to adsorb salts was measured, represented by measuring the (TDS) values of the treated water models.

Table (2) represents the variation in the ability of different sawdust granules in reducing (TDS). The best results were at the mixing and residence time between sawdust and water (15 minutes), as the highest removal efficiency of (TDS) were (16.07%) for fine sawdust, whose granule size ranged from (1-2 mm), followed by medium-sized sawdust with a removal efficiency of (14.10 %), while the coarse sawdust, whose grain size was greater than 4 mm, reached (7.4%) removal of (TDS) only. This is compatible with the findings of [20] that the ability of fine sawdust to adsorb is better than coarse sawdust due to increase the surface area of its granules.

The following equation was used to find the removal efficiency;

The efficiency (e) of the treated water is

$$e = \frac{(C1-C2)}{c1} * 100 \ldots\ldots equ. (1)$$

where e is the efficiency of the treated water, C1 is the parameter’s value before treatment, and C2 is the parameter’s value after treatment.

TABLE 2 The effect of particle size of sawdust on total dissolved salts of ground water

Saw dust	Particle Size	TDS Before Treatment ppm	TDS (ppm)					
			After 5 min	Efficiency Of removal %	After 10 min	Efficiency Of removal %	After 15 min	Efficiency of removal %
FS	> 1 mm	1910	1700	11.0	1662	12.97	1603	**16.07**
MS	> 2 mm	1910	1733	9.23	1715	10.22	1640	14.10
CS	> 4 mm	1910	1826	4.37	1788	6.34	1769	7.40
FS: Fine sawdust MS: Middle sawdust CS: Coarse sawdust								

Coarse mulch was excluded due to their low efficiency in removal. While medium sized mulch and fine mulch were adopted in subsequent experiments, and they represent the majority of mulch used. The average removal efficiency of medium-sized mulch and fine mulch was (15.01%), which was (2.17 times) over coarse mulch removal efficiency, This matches with [10], who obtained the best results when using a granule size of 2 mm, and [9], which proved that 2.36 mm sawdust gives best results.

Physical treatment was performed to increase the efficiency of the sawdust at the lowest concentrations of pollutants. Sawdust was washed several times with distilled water to get rid of the very fine sawdust and to increase the pores and the surface area of the sawdust granules. Different amount of distilled water was added several times to each (10 g) of dry, unwashed sawdust(as it actually is) until all unwanted materials are removed and the sawdust is kept in the required size. Table (3) shows the amount of salts that were removed after washing operations.

TABLE 3 The concentration of impurities (ppm) in distilled water after treatment

Washing Number	Quantity of washing distilled water		
	100 ml	150 ml	200 ml
	Concentration of impurities (ppm)		
First	160	120	80.9
Second	84	62.5	40
Third	24	17.2	11
Fourth	6.2	5.8	5.5

The high concentrations of dissolved salts in the distilled water used for washing indicates that the sawdust from carpentry factories contains very fine materials and impurities, The washing process leads to the disposal of unwanted materials, as well as an increase in swelling gaps for more adsorption (Active Site Adsorption) [24].

The removal efficiency and the ability of sawdust to absorb salts increase when the sawdust is washed with distilled water and when free of impurities. 250 ml of high salinity artesian well water from Al Kindy area of (1910 ppm) was treated with 10 gm of washed sawdust. The highest removal of dissolved salts was (24.18%). The percentage of salt removal was reduced to (16.23%) when the amount of polluted water was 1.5 times increased. When adding two times the amount of polluted water, the removal rate decreased to (12.67%) and decreased to (8.11%) when adding three times the amount of contaminated water. That is, the percentage of decrease in removal efficiency is inversely proportional to the percentage of increasing in the amount of polluted water. Table (4) shows the discrepancy in the amount of residual salts and removal rates at different residence times and the amount of contaminated water with (10 g) of dry washed sawdust, whose grain size was (>1 mm).

TABLE 4. Variation in the percentages of removal dissolved salts (TDS) with the amount of treated water and correlation of difference residue times(by column exchange).

Quantity of water (ml)	TDS of Raw water (ppm)	Periodic time treatment (min)					
		5 min		10 min		15 min	
		ppm of TDS	Efficiency removal %	ppm of TDS	Efficiency removal %	ppm of TDS	Efficiency removal %
250	1910	1620	15.18	1526	20.1	1448	24.18
375		1705	10.73	1660	13.09	1600	16.23
500		1772	7.22	1730	9.42	1668	12.67
750		1810	5.23	1782	6.7	1755	8.11

To calculate the capacity of sawdust to adsorbs salts , equation (2) can be used according to [3].

$$\text{qe} = \frac{co - ce}{m} \ldots \ldots . equ\ (2)$$

where qe : (mg/g) represents the adsorption capacity.

Co : (ppm) and Ce (ppm) is the initial and final concentration of pollutant respectively.

m : (g) is the weight of the dried adsorbents.

That is *Adsorption capacity =*

(raw water concentration. - treated water concentration)÷sawdust weight

(1910 ppm – 1448 ppm) = 462 ppm concentration Removal / 10 gm. of sawdust= 46.2 mg/gm

That is, each gram of treated sawdust has the ability to remove 46.2 mg/liter of polluted water with very high concentrations of dissolved salts, that each kg of sawdust when used for one time has the ability to remove 46.2 mg/m3 of polluted water. Which can be used in rural areas that provide sawdust and timber instead of using modern techniques in processing water.

To find the ability of sawdust used several times in adsorption after drying -as a physical treatment to uses sawdust- , 250 ml of high salt artesian well water was treated with 10 gm of drying used sawdust. It was observed that the percentage removal was reduced to more than half when used the drying sawdust for the second time, as well as in the third time of using the same sawdust, the TDS percentage removal decreased to more than half of the removal percentage from the second time. This confirms that the ability of sawdust in adsorption is affected by the volume of polluted water. Whether the amount of polluted water at one time or the number of treatment. While, physical treatment of sawdust with washing or drying after using several times will improve sawdust ability. The maceration period was affecting on the removal of TDS.

The results showed a decrease in the effect of the contact period of (5 and 10 minutes) in TDS removals, but in (15 min) the removal of TDS was improved. This is due to the saturation of the surface layer of sawdust granules in which it needs more time in treatment [7]. Table (5) shows the clear differences in the concentrations and percentages reduction of TDS in raw well water when the treatment process is repeated for the same sawdust and the different contact times.

To study the ability of sawdust in adsorption to reduce the concentrations of different salts from water, surface water was used for the treatment, as the concentration of dissolved salts is less than that of groundwater. Water of the Al-Khosur River near its estuary was used, with TDS reached (1055 ppm), and the water of Tigris River from the middle of the city of Mosul, with an amount of TDS (588 ppm). The adsorption level equilibrium depending on many agents, some of them were explained by the researchers [11], who define the equilibrium grade of adsorption level as a function of the pH value, temperature, contact time, adsorbent dose and the initial concentration of adsorbed materials. The concentration and the adsorption performances significantly depend on the adsorbent's particle size. Smaller contaminant particles can adsorb more readily onto the adsorbent than larger contaminant particles [13].

TABLE 5 Variation in the percentages of dissolved salts removal with repeated use of sawdust and at difference residue times

No. of sawdust treatment	TDS of raw water (ppm)	Periodic time treatment (min)					
		5 min		10 min		15 min	
		ppm of dissolved salt	Efficiency removal %	ppm of dissolved salt	Efficiency removal %	ppm of dissolved salt	Efficiency removal %
First	1910	1620	15.18	1526	20.1	1448	24.18
Second		1783	6.63	1722	9.80	1625	14.92
Third		1810	5.23	1767	7.48	1725	9.68

Water was treated for a period of 15 minutes with the washed and dry sawdust and for several times (three times) for the same mulch. The results proved a high percentage of salt removal for low-concentration water with that of high-salinity well water due to the lack of saturation of the sawdust grains with salt. The difference in removal rates when using the same sawdust double and triple is small for low-concentration water. Table (6) shows the clear differences in the percentages of removal and residual dissolved salts of the treated water samples expressed as electrical conductivity (EC) and total dissolved salts (TDS).

As for the pH values of the water models used, which is a measure of the presence of various ions that cause the presence and activity of the hydrogen ion (acidity function), the decrease in the concentrations of dissolved salts had a clear effect in reducing the pH values and approaching the state of moderation at the values near (pH 7). This means that the adsorbed salts are salts bound to the hydroxide ion (OH^{-1}). Changing in the values of pH evinces the adsorption processes [20].

Hardness and alkalinity salts as calcium, magnesium carbonate and or sulfate formed high percentages of dissolved salts in Mosul water resources. These ions, cations and anions are represented higher values of (E.C.) and (T.D.S.). These ions must be decreased to improve the quality of water. Sawdust decreased the values of these salts with percentage of removals near by the TDS percentage removals, as these salts consisting a large portions of TDS. Thence the ability of adsorption was nearby TDS percentage removals. Table (7) discus the values of total hardness, calcium , magnesium cations, sulfate, and carbonate anions.

TABLE 6 Variation of (pH values), (E.C.), (TDS) and efficiency of removal for different types of water qualities according to the number of sawdust used for the treatment

Parameters	Sampling location	Before treatment	Firstly uses	Secondly uses	Thirdly uses
pH values	Tigris river	7.60	6.85	7.03	7.12
	Al-Khosur River	7.45	6.77	7.03	7.12
	Al-Wahda site well	7.6	7.03	7.12	7.20
	Al-Kindy site well	7.80	7.10	7.21	7.33
E. C. µmos/cm	Tigris river	500	270	327	382
	Al-Khosur River	855	540	620	688
	Al-Wahda site well	1113	781	875	930
	Al-Kindy site well	1680	1270	1430	1517
TDS ppm	Tigris river	588	318	384	448
	Al-Khosur River	1055	670	766	850
	Al-Wahda site well	1295	910	1019	1085
	Al-Kindy site well	1910	1448	1625	1725
Efficiency removal %	Tigris river	0	45.92	34.6	23.8
	Al-Khosur River	0	36.5	27.4	19.43
	Al-Wahda site well	0	29.7	21.3	16.21
	Al-Kindy site well	0	24.18	14.92	9.68

Table 7 Differences in total hardness and some cations, anions of water samples through treatment with sawdust many times in ppm

Parameters	Sampling locations	Values before treatment	Firstly Uses Sawdust	Secondly Uses Sawdust	Thirdly Uses Sawdust
Total Hardness as $CaCO_3$	Tigris river	220	126	145	172
	Al-Khosur River	424	292	310	345
	Al-Wahda site well	511	368	398.8	430.2
	Al-Kindy site well	762	588.3	648.2	692.6
Calcium Ca^{+2}	Tigris river	58.3	34.2	39.4	45.6
	Al-Khosur River	112	72.2	86.4	96.6
	Al-Wahda site well	136.6	96.3	106.6	118.9
	Al-Kindy site well	208.8	160.4	181.3	191.4
Magnesium Mg^{+2}	Tigris river	24.2	16.2	18.1	20.4
	Al-Khosur River	44.2	29.6	33.8	37.4
	Al-Wahda site well	58.3	42.2	45.8	50.8
	Al-Kindy site well	80.6	60.3	69.8	73.6
Sulfate SO_4^{-2}	Tigris river	64.6	38.5	43.7	49.4
	Al-Khosur River	120.3	79.5	88.8	97.4
	Al-Wahda site well	144.4	101.8	114.4	122.6
	Al-Kindy site well	180.2	138.5	155.5	164.5
Carbonate , Bicarbonate CO_3^{-2} HCO_3^{-1}	Tigris river	136.2	81.3	92.4	109.6
	Al-Khosur River	172.3	119.6	128.5	140.7
	Al-Wahda site well	196.1	144.2	158.5	168.6
	Al-Kindy site well	355.3	272.8	312.8	328.7

To explain the variations in percentage removal of salts in the different water samples. Fig(3) showing these variations with range of 45.92% removal of TDS of Tigris river in the 1st use and decrease to 11.2% removal in the 4th uses of the same sawdust. These percentages decreased with increasing TDS . In Al-Kindy well water with a primary TDS of the raw water was 1910 ppm, the removal of salts was 24.18 in the 1st use and decrease to 3.2% in the 4th uses.

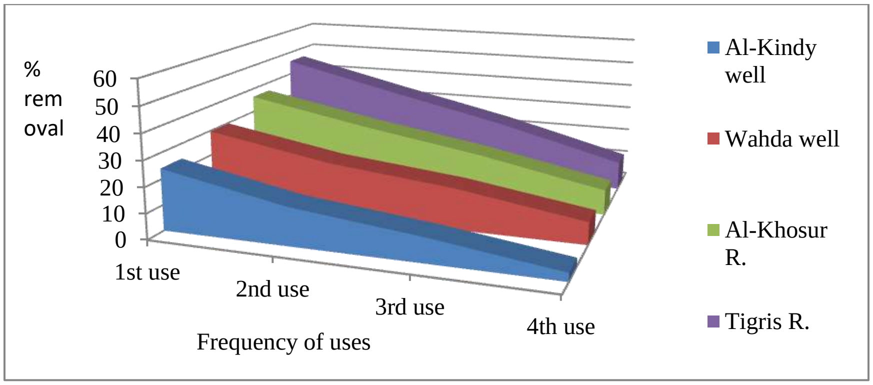


Figure3: Percentage removal of TDS in different water locations with multiple uses

Adsorption by sawdust given a high quality purified product. The use of this absorbance is of low-cost bio sorbents is recommended since it is relatively cheap or of no cost, easily available, renewable and show highly affinity for dissolved materials.

4. Conclusions

1- Sawdust is an accidental product of the carpentry works that were previously used for heating and for the floors of poultry fields (uses of limited interest).

2- Sawdust is an adsorbing material that has the ability to adsorb ions and dissolved salts and reduce their concentrations in water.

3- Adsorption, by sawdust is used in order to increase the use of more eco-friendly and economical water treatment methods.

4- Under the principal of water harvesting, quality of water must be done suitably for the different uses, by using suitable materials in treatment and natural by- product materials as sawdust is a good example..

5- The highest removal percentage of unwashed fine sawdust reached (16.09%), while it decreased to (7.4%) for coarse sawdust due to the increase in the surface area of the adsorbent material in the fine grains sawdust.

6- The adsorption capacity of the washed sawdust increases compared to the unwashed sawdust due to the removal of dust and an increase in swelling gaps.

7- The highest rate of adsorption and removal of dissolved salts for washed sawdust was (45.92%) for low TDS (588ppm), and decrease with increasing TDS of raw water, it reaches (24.18%) for V. high TDS of (1910 ppm) .

8- Each one kg of treated sawdust by washing and drying has the ability to adsorb and remove (46.2 mg / m^3) of dissolved salts, which is equivalent to (46.2 ppm/ m^3) of polluted water.

5. Recommendations

1- Study of increasing the efficiency of sawdust on removal and adsorption using cheap local materials.

2- A study of reactivating sawdust to be used several times.

3- Using other types of sawdust and studying their ability to remove.

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