Study of using rubber tires waste as a media in the constructed

Shadi Mohamad Takla*   Ghada Abdulkarim Bilal[1]

* PhD student at environment and sanitary of faculty of civil engineering – Damascus university.

[1] Assistant Professor at environment and sanitary of faculty of civil engineering – Damascus university.

ABSTRACT:

Constructed Wetlands are easy to establish, simple to operate, do not need staff or supervisors and can be monitored and managed by one person, in addition to being environmentally friendly as they do not result in any undesirable effects in it. These plants consist of natural materials represented by gravel materials, soil and plants, where gravel materials are placed in the form of layers so that they form the filler in the treatment basins while plants are planted on the surface of the basin to extend their roots later into the gravel filter (the filler material) and absorb pollutants where they are used in their growth, where gravel fillers are placed in the form of layers while plants are planted on the surface of the basin to extend their roots later into those layers, and they absorb pollutants where they are used in their growth.

The idea of the research is to study the possibility of using one of the solid waste materials, which is rubber tires waste as a filler in plant basins within constructed wetlands and to consider it as a new medium and vital carrier of flow within those basins instead of the
usual gravel filter and compare it with the alternative filler material in whole or in part, that is, by combining the gravels with the rubber pieces and evaluating the efficiency of the alternative filler material in raising the efficiency of treatment and removing pollutants, Thus، this kind of waste are disposed of in an environmentally safe manner or at least reducing their harmful environmental effects. In addition to explore the possibility of creating biological diversity within plant basins in the constructed wetlands by studying the possibility of producing several types of plants. All of this will reflect positively on reducing the cost of treatment, whether by comparing the cost of the alternative filter with the cost of usual gravel filter, choosing the best alternative, saving in the area of the basins, or recycling rubber tires waste, as well as on the environmental aspect and water specifications resulting from treatment.

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دراسة استخدام نفايات الإطارات المطاطية كمادة مالئة في الأراضي الرطبة الصنعية

شادي محمد تقلا* غادة عبد الكريم بلال[1]

*طالب دكتوراه في قسم الهندسة الصحية والبيئية – كلية الهندسة المدنية – جامعة دمشق.

[1] أستاذ مساعد في قسم الهندسة الصحية والبيئية – كلية الهندسة المدنية – جامعة دمشق.

الملخص:

إن محطات المعالجة بالنباتات (الأراضي الرطبة الصنعية) هي محطات سهلة الإنشاء، بسيطة التشغيل، لا تحتاج إلى طاقم عمال أو مشرفين ويمكن مراقبتها وإدارتها من قبل شخص واحد، بالإضافة لكونها صديقة للبيئة حيث لا ينتج عنها أي تأثيرات غير مرغوب

فيها. تتكون هذه المحطات من مواد طبيعية تتمثل بالمواد الحصوية والتربة والنباتات، حيث يتم وضع المواد الحصوية على شكل طبقات بحيث تشكل المادة المالئة في أحواض المعالجة بينما يتم زرع

النباتات على سطح الحوض لتمتد جذورها فيما بعد إلى داخل الفلتر الحصوي (المادة المالئة) وتقوم بعملية امتصاص للملوثات حيث تستخدمها في نموها، حيث يتم وضع المواد المالئة الحصوية على شكل طبقات بينما يتم زرع النباتات على سطح الحوض لتمتد جذورها فيما بعد إلى داخل تلك الطبقات، وتقوم بعملية امتصاص للملوثات حيث تستخدمها في نموها.

تتلخص فكرة البحث في دراسة إمكانية استخدام إحدى مواد المخلفات الصلبة وهي نفايات الإطارات المطاطية كمادة مالئة في أحواض النباتات ضمن الأراضي الرطبة الصنعية واعتبارها وسيط جديد وناقل حيوي للتدفق ضمن تلك الأحواض بدلاً من المواد الحصوية الاعتيادية ومقارنتها مع المادة المالئة البديلة كلياً أو جزئياً أي من خلال دمج الحصويات مع القطع المطاطية وتقييم كفاءة المادة المالئة البديلة في رفع كفاءة المعالجة وإزالة الملوثات، وبالتالي يتم التخلص من تلك المخلفات بطريقة آمنة بيئياً أو على الأقل تخفيف آثارها البيئية الضارة. مع بحث إمكانية إيجاد تنوع حيوي ضمن أحواض النباتات في الأراضي الرطبة الصنعية من خلال دراسة إمكانية إنتاج عدة أنواع من النباتات. كل ذلك سينعكس إيجابياً على تخفيض كلفة المعالجة سواء من خلال مقارنة ثمن المادة البديلة بثمن البحص واختيار البديل الأفضل أو توفير في مساحة الأحواض أو إعادة تدوير نفايات الإطارات المطاطية، وكذلك على الناحية البيئية ومواصفات المياه الناتجة عن المعالجة.

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كلمات مفتاحية: الأراضي الرطبة الصنعية، أحواض المعالجة البيولوجية، مادة مالئة، نفايات الإطارات المطاطية، كفاءة المعالجة.

Introduction:

Wastewater treatment has been a global problem since the discovery that dumping waste into surface water may results many additional environmental problems. Traditional sanitation technology has often been unsuccessful in developing countries due to complex operating supplies and costly maintenance procedures (Nelson et al., 2012). Constructed wetlands are considered a sustainable technical, economic, and environmental solution for wastewater treatment in small communities because they are effective in removing diverse pollutants (Araújo et al., 2008; Chen et al., 2008). Constructed wetlands are easy to established, simple to operate, do not require staff or supervisors and can be monitored and managed by a single person, in addition to being environmentally friendly as they do not produce any undesirable effects (S.Vidal; G.Hormazábal, 2018).

Wetland fillers can contain two or more types of media in variable layers. In practice, gravel is the media widely used in constructed wetlands (Zidan et al., 2013). (Collac,o and Roston, 2006) has successfully investigated the use of shredded tires as a wetland intermediate for the treatment of subsistence wastewater grown by large aquatic plants. (Cordesius and Hedström, 2009) investigated the use of gravel pieces and plastics in the treatment of living wastewater with advances in plastic media. Recycled plastic pipes and torn tire pieces have proven to be a good way to treat municipal wastewater (Abdulhadi, 2014).

This research will focus on the waste material of rubber tires to form a filtration media in constructed wetlands, and the feasibility of its use in the treatment of wastewater pollution by plants will be studied. Rubber waste itself poses a serious environmental threat. Emphasis was also placed on two types of plants, the reed and an ornamental plant, where ornamental plants play an important role in removing sewage pollutants as well as giving a breathtaking aesthetic view.

Thus, the main objectives of this study are:

- Choosing an alternative filler for gravel in constructed wetland basins from one of the solid waste materials to mitigate its harmful effects on the environment, on the other hand for saving the cost of traditional gravel filler within the basins and its contribution to the removal of sewage pollutants while alleviating the problem of clogging the filler.
- Use rubber tires waste as a filler in constructed wetlands and determine the extent of its impact on the effectiveness of wastewater treatment, and make a comparison between the two types of gravel and rubber filler, while studying the options of combining them.
- Verifying of the possibility of producing plants with an aesthetic view within constructed wetlands, while at the same time determining the extent to which the type of plant affects the efficiency of treatment.

Literature Review:

The literature studies were classified into two main objects:

1- The Studies related to the use of rubber tires waste as a filler in the constructed wetlands:

- A Study prepared by (Robert H. Kadlec,Scott D. Wallace) in the United States of America in 2009, entitled (KADLECWALLACE 2009 Treatment Wetlands 2nd Edition), which focused on developments of monitoring the operation of sewage treatment systems within wetlands, where they explained that during the last decade, wetlands have developed technologically. There is a problem that many graduate studies focus on short-term events. For example, clogging of filtration layers within wetlands has not been studied in a systematic way, because monitoring of the clogging phenomenon takes longer than the postgraduate student's period of work.

- A Study prepared by (Alexandros I. Stefanakis, Vassilios A. Tsihrintzis) in Greece in 2009 (Use of various substrates as filter media to treat the effluent of a Vertical Flow Constructed Wetland), which focused on the feasibility of using different substrates as filter media to treat vertical flow effluents in constructed wetlands by creating four gravity filters on an experimental scale, containing different filter media (zeolite, bauxite, and a mixture of zeolite and bauxite), the results showed that all filters improved the quality of wastewater in wetlands. The use of zeolite and bauxite significantly improved nitrogen and phosphorus removal.
- A Study prepared by (A.Morvannou, N.Forquet, M.Vanclooster, P.Molle) in France in 2013 entitled (Use of various substrates as filter media to treat the effluent of a Vertical Flow Constructed Wetland) about the modeling of the sewage system recommended the need to characterize the hydraulic properties of the filter materials used in vertical flow wetlands, which they considered as a model adopted in their research, and considered this a prerequisite for the modeling of the sewage treatment system. They described the filter material as a matrix of porous metallic materials and organic materials that makes hydraulic characterization a somewhat difficult task.
- A Study prepared by (Mohamed Ahmed, Ali Rashed, Mahmoud EL-Gamal, Abdel Razik Zidane, Ahmed Abdel Hady Eid) in Egypt in 2015, entitled (Wastewater treatment in horizontal subsurface flow constructed wetlands using different media), tested and compared wastewater treatment through horizontal subsurface flow of wetlands (CWs) using three different treatment methods (gravel, plastic pipe cuttings and rubber tires waste) in the village of Samaha, Dakahlia, Egypt. The results showed that the efficiency of treatment and removal of contaminants must be considered as the research period was not sufficient, especially the first months of adaptation gave close results, and the superiority of gravel in removing BOD, COD and TSS, the superiority of plastic in terms of porosity, and the superiority of waste rubber tire pieces was often observed. The researcher made a recommendation that more research should be conducted and a broader comparison of the feasibility of using local alternatives to filtration media gravels.
- A Study prepared by (Alfredo García-Pérez, Mark Harrison, Craig Chivers, Bill Grant) at Lagrange University in the United States of America in 2015, entitled (Recycled Shredded-Tire Chips Used As Support Material in a Constructed Wetland Treating High-Strength Wastewater from a Bakery), the researchers proved that the supporting materials used in constructed wetlands are an essential element and an important mechanism in the process of removing contaminants from wastewater, including phosphorus

compounds. Waste recycled tires, after being cut into small slices similar to conventional gravels used in filtration basins, have shown high efficiency in removing phosphorus from wastewater.

This researchers eventually concluded that waste tires could be an environmentally friendly alternative as supporting materials in plant plants, through practical results. The high efficiency of phosphorus removal (65%) can be explained by the presence of metals, specifically iron from exposed wires of tire foil. Any phosphorus present in wastewater can react with iron resulting in non-degradable phosphorus compounds. At the end of the research, the researchers recommended that early applications of recycled shredded tire chips in built-up wetlands would serve as the initial foundation point for improvement, refining, and developing better future generations of wastewater treatment.

- A Study prepared by (Derakhshan, Ghaneian, Mahvi, Oleveri Conti, Faramarzian, Dehghani, Ferrante) in Iran in 2017, entitled (A new recycling technique for the waste tires reuse), which is a series of practical experiments, in which an experimental model was used to study the kinetics of substrate consumption in biofilms using waste tires (polyamide filaments) as an intermediate within plant treatment plants. The feasibility of using fixed-layer biofilm carriers manufactured from waste tires for wastewater treatment was assessed. Results of increased processing efficiency and lower sludge production were recorded. The results of this study indicate the feasibility of using a waste tire rubber rack to support biological activity for a variety of wastewater treatment applications as it has shown high potential and better performance such as COD and TSS removal, lower sludge deposition and better quality of the resulting water.
- A Study prepared by (Jih-MingChayan, Delia-B.Senoro, Chien-JungLin, Po-JaiChen, I-MingChen) in Taiwan in 2019, entitled (A novel biofilm carrier for pollutant removal in a constructed wetland based on waste rubber tire chips), focused on rubber tires as a material that poses a serious threat to environmental protection, and as a step to recycle it, rubber tire chips were introduced as new media and a vital carrier for subsurface flow of wetlands, which are combined with the surface of free water to form a hybrid experimental system. The comparison between the traditional gravel material and the rubber foil gave good results for the alternative material and the success of its use, as due to some steel belts within the foil, iron ions are released naturally in the treatment basins.
- A Study prepared by (Bruce Lesikar, Richard Weaver, Amanda Richter, Courtney O'Neill) in Texas, USA in 2019, entitled (A new recycling technique for the waste tires reuse Constructed wetland media), focused on the effective treatment of domestic wastewater, Wetland systems designed with subsurface flow can contain the right types of media, such as sand, gravel and tire fragments, and the media must be properly configured, and the system must be regularly maintained. They identified the processes that take place during the treatment process (filtration, sedimentation, nitrification, denitrification, adsorption, as well as plant stabilization and growth support). The researchers also identified the ideal sizes of rubber pieces where the size of the media particles greatly affects the ability of the system to work, as small pieces provide a larger surface on which microorganisms that feed on wastewater pollutants live, but very

small pieces are prone to clogging. They also set the criteria for choosing the type of substrate within the vegetation treatment basins (porosity, stability, media size, surface area, aesthetic). They also laid down special instructions to maintain the wetland system established to function properly, emphasizing the need to maintain all components in the system.

- A Study prepared by (St. Joseph, Michigan) in USA, 2013, Entitled (Phosphorus Reduction in Effluent from Suppurface Flow Constructed Wetlands Filed with Tire Chips), recently published by 2021 by the American Society of Agricultural and Biological Engineers (ASABE) and on the website (www.asabe.org), the researchers focused on the importance of sub-surface flow wetlands (SFCWs) for on-site wastewater treatment. Although gravel is the most common type of filter media in wetlands, the excessive abundance of waste tires has made it a justification for their use as alternative and efficient media. Fractured rubber tires are less dense and less expensive than gravel. This study focused on the ability of a medium filled with rubber tire pieces to remove the phosphorus content in living wastewater. A greater reduction in phosphorus was observed in wetlands filled with tire flakes because iron from exposed wires in ruptured steel tires combined with phosphorus in sewage to form non-degradable phosphorus compounds. Tire flakes are thus a better filler than gravel due to the high porosity, low cost, and greater reduction of phosphorus in the resulting water.

2- The Studies related to the effects of plant and filter material types in the constructed wetlands on the treatment efficiency and production of ornamental plants:

- A Study prepared by f Dr. Ghada Bilal, Damascus University (2013) entitled (Control of nutrient concentrations in wastewater using local plants as tertiary treatment), aimed to treat wastewater resulting from traditional treatment plants by treating local aquatic plants, as a good system for controlling and reducing pollutants as an alternative to traditional tertiary treatment plants for wastewater. The researcher relied on the establishment of an experimental plant treatment plant as a tertiary treatment stage, which relies on the use of three types of native plants to remove or reduce the concentration of nitrogen and phosphorus (zal, tyva, and ptimos) by planting them in three independent basins as a first stage, and then planting the river lentil plant in two additional basins as a second stage, and it is assumed that the water after treatment will turn into water suitable for irrigation.

  One of its most prominent results was that controlling the concentrations of pollutants in treated water requires controlling the hydraulic surface loading, the rates of recycling of treated water, as well as the type of plant used within the basins, as the cane plant gave good results in removing pollutants compared to other plants except for phosphorus removal. It was noted that the removal yield was low in all basins, and the researcher recommended the need for subsequent research in terms of raising the rate of phosphorus removal, and also recommended that new research be carried out on plants treatment plants within our country, Syria, commensurate with its conditions.

- A Study prepared by (Shubiao Wu, Peter Kuschk, Hans Brix, Jan Vymazal, Renjie Dong) in Denmark in 2014, entitled (Alternative to gravel stones for filter media of Constructed Wetland), dealt with the topic of improving constructed wetlands in Denmark. They studied an alternative to gravel stones as a traditional filter medium for constructed wetlands such as organic sawdust or a mixture of gravel sawdust. The researchers reached several results, the most important of which was that the development of the nature of the filtration medium with local materials contributes to improving the efficiency of the basins to remove pollutants in wetlands with vertical flow, while in basins with horizontal flow, traditional gravel seems more effective.
- A Study prepared by Dr. Al-Abed Ibrahim, Algeria (2015) entitled (Wastewater treatment of a region by local purified plants), dealt with the ability of plants (Typha latifolia7, Juncus ffuses, Cyperus papyrus) to purify wastewater.

  The results showed that the percentage of activity varies from one plant to another, and Typha latifolia has great effectiveness in treatment, and is considered a plant with remarkable activity and the most developed and stable, as it gave better results in terms of its performance and ability to remove organic materials and phosphorus, followed by 7 Juncus ffuses and Cyperus papyrus, and there is no difference in removing nitrites, nitrates and bacteria for the three plant species. With regard to physical and bacteriological media, the purification capacity of plant-infused basins was higher than in non-implanted basins (witness).
- A Study prepared by (Cristina S.C.Calheiros, Vânia S.Bessa, Raquel B.R.Mesquita, HansBrix, António O.S.S.Rangel, Paula M.L.Castro) in Portugal in 2015, entitled (Constructed wetland with a polyculture of ornamental plants for wastewater treatment at a rural tourism facility), in which a horizontal subsurface flow system was established in a guesthouse located in a rural and mountainous area of Portugal. The bed substrate was a clay substrate, cultivated from multiple flowering ornamental plants (Canna flaccida, Zantedeschia aethiopica, Canna indica, Agapanthus africanus, Watsonia borbonica). The removal efficiency of BOD and COD is generally high (> 90%) and independent of load conditions. The system also reduced PO43 − (up to 92%), NH4 + (up to 84%) and total coliform bacteria (up to 99%). A. africanus is relatively superior to other plants. Plant treatment plant systems grown with different types of ornamental plants, in addition to the water treatment function, have been shown to have many additional benefits including aesthetics and enhanced biodiversity.
- A Study prepared by (Sergio Zamora, Luis Sandoval, J. LuisMarín-Muñíz, GregorioFernández-Lambert, and M. Graciela Hernández-Orduña in Mexico in 2015, entitled Impact of Ornamental Vegetation Type and Di erent Substrate Layers on Pollutant Removal in ConstructedWetland Mesocosms Treating Rural Community Wastewater, compared two ornamental plants (Spathiphyllum wallisii and Hedychium corarium) grown in experimental units filled with layers of porous river rock and soil, or in units of porous river rock layers, without soil. The study showed that both types of plant are suitable for use in

plant treatment plants, in terms of their functions as plant treatment and aesthetic advantages that can generate interest in wastewater treatment in rural communities, parks, schools or in residential buildings as flower beds in the outdoor courtyard.

- A Study prepared by (Cristina Macci, Eleonora Peruzzi, Serena Doni, Renato Iannelli, Grazia Masciandaro) in Italy in 2015, entitled (Ornamental plants for micropollutant removal in wetland systems) aimed to evaluate the efficiency of removing micro pollutants such as copper, zinc, carbamazepine and kilobenzene sulfonate from industrial wastewater, through the use of a sub-surface vertical flow wetland system with ornamental plants (Zantedeschia aethiopica, Canna indica, Carex hirta, Miscanthus sinensis and Phragmites australis) , and planted in gravel-filled basins. Nutrients (N and P) and heavy metals were significantly reduced due to both plant activity and absorption. C. indica and P. australis showed the highest mineral content in their tissues while Z.aethiopica was the least efficient plant in removing organic and mineral compounds.
- A Study prepared by Dr.Ibrahim Omar Saeed, Iraqi University of Tikrit (2017) entitled (Field survey of aquatic plants growing in sewage and their use in pollution treatment). This study was conducted in the faculties of environment and education in the universities of Mosul and Tikrit and included a field survey to estimate some physical and chemical qualities of water as well as estimating some heavy elements of some aquatic plants in addition to conducting laboratory experiments to treat sewage using water lentils and saad plants.

  The results of the study indicated that the values of physical and chemical qualities increased, while the values of these elements increased significantly at the sewage sites compared to the Tigris and liquefaction water sites, and high values of heavy elements were recorded at the well water sites. The results of the study also showed that the bioaccumulation of heavy elements in cane is higher than that of the papyrus plant, and the results of the laboratory study of water lentil treatment experiments showed that it has the ability to withdraw heavy elements from the medium in which it lives and collect them inside it, and thus reduce their concentrations in the treated water. It was found that the type of plant used in plant plants has an impact on the removal efficiency of contaminants.
- A Study prepared by (Ana María Leiva, Romina Núñez, Gloria Gómez, Daniela López, Gladys Vidal) in Chile in 2018, entitled (Performance of ornamental plants in monoculture and polyculture horizontal subsurface flow constructed wetlands for treating wastewater), the aim of this study was to assess the impact of two ornamental plants (Cyperus and Zantedeschia aethiopica) in basins with horizontal subsurface flow for wastewater treatment. The efficiencies of removal of organic matter, suspended solids, nutrients and pathogens during the years of operation were above 60%, 90%, 10% and 1.8 log respectively, with no statistically significant differences between the two plant species. It was concluded that planting basins with both plant types together was a good alternative in terms of processing efficiency as well as other benefits, such as improving the system landscape.

- A Study prepared by (Luis Carlos Sandoval-Herazo, Josè Luis Marín-Muñiz, María Graciela Hernández y Orduñas, and Antonio Janoary Aleman-Chang) in Mexico in 2018, entitled (Role of wetland plants and use of ornamental 3 flowering plants in constructed wetlands for wastewater treatment).

  and study (Sergio Zamora, J. Luis Marín-Muñíz, Carlos Nakase-Rodríguez, Gregorio Fernández-Lambert, Luis Sandoval) in Mexico in 2019, entitled (Wastewater Treatment by Constructed Wetland Eco-Technology: Influence of Mineral and Plastic Materials as Filter Media and Tropical Ornamental Plants).

  and study (Sergio Zamora, Luis Sandoval, J. LuisMarín-Muñíz, Gregorio Fernández-Lambert, M. Graciela Hernández-Orduña) in Mexico in 2019, entitled (Impact of Ornamental Vegetation Type and Different Substrate Layers on Pollutant Removal in Constructed Wetland Mesocosms Treating Rural Community Wastewater).

  (Luis CarlosSandoval-Herazo, AlejandroAlvarado-Lassman,María Cristina López-Méndez, AlbinoMartínez-Sibaja, Alberto A. Aguilar-Lasserre, Sergio Zamora-Castro, José Luis Marín-Muñiz) in Mexico in 2020, entitled (Effects of Ornamental Plant Density and Mineral/Plastic Media on the Removal of Domestic Wastewater Pollutants by Home Wetlands Technology).

  The previous four studies focused on testing several species of ornamental plants and for different filters. It was concluded that the use of flowering ornamental plants in plant plants is an excellent option, and efforts should be made to achieve this by increasing the adoption and use of these types of systems in residential, rural and urban areas.

- A Study prepared by (D.Kotsia, A.Deligianni, n.m.Fyllas, a.s..Stasinakis, M.S.Fountoulakis) in Greece in 2020, entitled (Converting treatment wetlands into “treatment gardens”: Use of ornamental plants for greywater treatment), used ornamental plants (Pittosporum tobira, Hedera helix) as vegetation cover for vertical flow wetlands for graywater treatment, with the aim of improving the aesthetic view. The results show that both species of the plant Pittosporum tobira and Hedera helix can grow in plum plant beds powered by gray water without any visible symptoms. These species withstand drought and flood conditions, making them ideal for use not only in residential buildings but also in seasonal hotels and holiday homes. The phosphorus content was gradually reduced from 100% during the first months of operation to 15% during the second year of operation. In addition, the total concentration of coliforms decreased by 2.2 logarithmic units in wastewater in all planted systems, while a decrease in removal efficiency was observed in the absence of plants. Overall, the “treatment gardens” proposed in this study provide a technically and economically feasible solution for treating greywater, with the added benefit of improving the aesthetic of urban, peri-urban and tourist areas.

The previous studies directed us to apply the components of the research and achieve its objectives by conducting an applied practical model that contains the basic elements of the constructed wetland system in miniature dimensions that meet the requirements of international and local codes regarding the reuse of rubber tires waste as a filler material in addition to the traditional filler material represented by gravels and making a technical, economic and environmental comparison between them, especially since rubber tires waste are in themselves a major environmental challenge in addition to the operational problems of constructed wetlands and the creation of biological diversity within the system and then modeling the system to computerize the best treatment system and decision-making.

Materials and Methods:

1. **Design of the Pilot:**

The Pilot of the constructed wetlands was designed and implemented within the Faculty of Agriculture at the Damascus University in order to apply the proposed research plan. This plant was designed according to the design parameters contained in the German code ATV-DVWK - 262. Water treatment is carried out according to two main stages:

The first stage: The primary treatment of wastewater, including the collection and sedimentation tank.

The second stage: The secondary treatment of wastewater includes the three basins for treatment with cane parallelly.

Figure (1) shows the technological scheme of the pilot station.

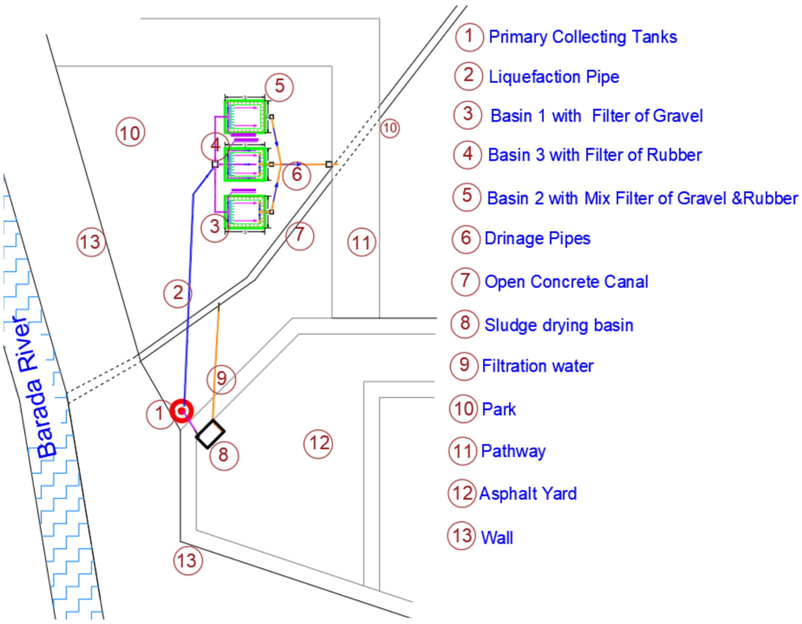

Figure (1): The technological line of the experimental station.

The pilot plant consists of the following installations:

1.1. Water Pump from the drainage network to the primary sedimentation tank:

This pump was placed in the sewage manhole inside a 55cm high barrel, which was provided with longitudinal cracks on its outer perimeter (each 10cm long and 5mm wide). The barrel is also covered with a metal mesh with 5mm holes, to prevent the entry of large suspended materials in the river water in order to reduce the pollution load in the post-treatment facility, and to prevent damage to these materials to the pump.

The water is pumped to the collection and sedimentation tank by the pumping pipe used of polyethylene (PE) material.

2.1. Primary Sedimentation Tank:

The capacity of the tank is 1 m^3/ made of PVC, in which the flocs in the water are disposed of and the granular bodies with small diameters are disposed of. The residence time in the tank ranges between (1-2) hours in which the water is separated from the sludge that collects at the bottom of the tank, where it is withdrawn to the sludge drying basin by a polyethylene pipe equipped with plastic sugar.

The water is pumped by liquefying from the collection and sedimentation tank to the main distribution tank by securing a 1% gradient difference and by a polyethylene (PE) pipe equipped with plastic sugar at the outlet of the collection and sedimentation tank.

3.1. Sludge Drying Basin:

A cement basin with dimensions of (2*1) m and a depth of 0.4 m, a layer of sand was placed in the floor of the basin with a thickness of 5cm to protect the insulation layer, then the insulation layer was placed on the floor and sides of the basin to prevent leakage, after which drainage pipes were installed over the insulation layer and collected in a complex to be drained into a concrete channel adjacent to the basin.

Figure (2): Sludge drying basin.

4.1. **Main Water Distribution Tank to Plant Treatment Basins:**

The capacity of the tank is 0.1m^3 Made of plastic, each of the subsequent plant basins is fed by pumping with liquefied water by securing a 1% tilt difference and by means of two polyethylene pipes, plastic scourers are installed on the basin feed pipes at the outlet of the distribution tank to control and measure the abundance entering the plant basins.

5.1. Plant treatment basins:

Figure (3) shows the treatment basins of the three plants according to their roles, the type of filter material in each of them and the mechanism of entry and exit of water from it.

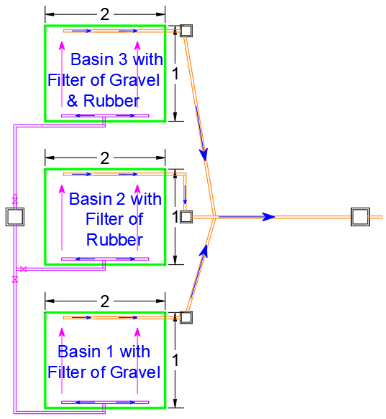

Figure (3): Plant treatment basins.

Whereas, it was adopted in the calculation of plant fields:

- on the hydraulic load contained in the said code ≥ 6 l/m^2.min
- The time period between two consecutive loads ≥ 2-6 hours.
- The area of the basin section is calculated from the relation:

$$A=Q/24*v$$

A: Tank section area (m^2).

Q: Raw water flow (m^3/d).

v: Vertical flow velocity in the tank (m/h).

Based on these parameters, an area of (2*1) m and a depth of (0.75m), and a 1% slope were selected for each of the three basins, which were planted with canes and with three different types of filler material (the first with a rubber filter, the second with a gravel filter, and the third with a gravel-rubber mixed filter). Accordingly, the abundance entering the station was 6 m^3/h, i.e., 2 m^3/h for each basin (within one hour is the loading period of the basins with water), so that the filtration time between two consecutive loads is 2 hours, knowing that this abundance was withdrawn from the main distribution tank immediately preceding the basins.

As for the filler material (filter), it is as follows:

1- **Gravel Filter Basin:** The gravel treatment filter consists of three layers from the bottom to the top, starting with a layer of gravel with a thickness of (15cm) and a gradient of (10-25) mm, then a layer of sand with a thickness of (50 cm) and a gradation of (0.4 mm), and finally a layer of gravel with a thickness of

(10 cm) and a gradation of (10-25) mm, so that the height of the basin is (0.75cm)), figure (4) shows the basin with gravel filter.

2- **Rubber Filter Basin:** The rubber treatment filter consists of a layer of pieces of rubber tires waste at a dimension of (0.8-2) cm, and with a height of the basin (0.75cm), figure (5) shows the basin with rubber filter.

3- **Mixed-filter basin:** The mixed treatment filter consists of three layers from the bottom to the top, starting with a layer of gravel with a thickness of (15cm) and a gradient of grain (10-25mm), then a layer of Mazar sand with a thickness of (10cm) and a gradient of grain up to (0.4mm), and a layer of rubber and gravel mixture with a gradient of grain (10-25mm), so that the height of the basin is (0.75cm)), figure (6) shows the basin with rubber filter.

Figure (4): Basin with gravel filter. **Figure (5): Basin with rubber filter.** **Figure (6): Basin with mixed filter.**

6.1. Manholes after plant beds:

These manholes are made of plastic with a capacity of 0.02 m^3, through which leachate is diverted from each plant basin to the final collection channel of the treated water by opening the dams within it. This is done by providing a 2% gradient difference and through pipes made of PVC.

Figure (7): Manhole.

7.1. Drainage network:

PVC pipes with a diameter of 3 inches collect water from the three manholes to an exposed concrete channel ending with the public drainage network.

2. Electrical and mechanical equipment:

The pilot plant is equipped with the following equipment:

- A pump provides sewage pumping from the public network to the collection and sedimentation tank with a capacity of 200l/min.
- A double circuit breaker, 32A secures manual operation of the pump as the work of the station is intermittent.

3. **Plant Types:** Two types of plants will be adopted during the study period:

- ✓ In the first stage: the plant is Cane that suits the climatic conditions of our country, as well as the traditional plant used in constructed wetlands, figure (8) shows the cane plant.
- ✓ In the second stage: The plant is an ornamental plant (Bougainvillea), which prefers to grow in temperate climates, it suits the climate of our country figure (9) shows the cane plant.

✓ .

Figure (8): Cane plant.

Figure (9): Ornamental plant.

Figure (10) shows the experimental plant treatment plant with its final placement after implementation and the cultivation of cane to start its growth within the basins.

Figure (10): Experimental plant pilot.

<u>The second stage:</u> It includes the practical pilot study, which is represented in:

- **Sampling**

Contaminants have been identified to determine their concentrations, and to monitor their changes within the water. Determine the necessary parameters:
(pH, cod, BOD, TSS, NH_3^+, NH_4^+, $N\text{-}NH_3$, NO_3, Po_4^{-3}).

- Before operating the plant and starting sampling and conducting experiments on it, the rubber waste sample was tested as follows:

In order to test the durability of the rubber filter material in the wastewater and at the same time change the specifications of the wastewater due to the rubber material, a sample of the rubber filter material was prepared and placed in a container equipped with a tap and washed with water and then with wastewater for about two weeks and then start the test on the incoming and outgoing water.

Figure (11): Rubber tire waste sample slicing and processing.

Figure (12): Rubber tire waste sample washing.

Figure (13): Adding wastewater to the sample.

Figure (14): Harvesting water samples to conduct experiments

Figures (15,16,17,18): Conducting experiments on samples in the water laboratory.

The results were documented in special tables with a simplified diagram showing the change in the values of the parameters according to four experiments at the rate of one experiment per month.

Test Number / 3 /	Date of Test			
	Input	Output _ 1	Output _ 2	Output _ 3
Test time / 11:00 am /	16/1/2023	17/1/2024	21/1/2024	25/1/2024
BOD_5 (mg/L)	320	280	220	180
COD (mg/L)	417	438	441	463
TSS (mg/L)	280	210	285	293
NH_3 (mg/L)	52.5	52.7	57	58
$N\text{-}NH_3$ (mg/L)	42.8	43	46.3	47.5
NH_4^+ (mg/L)	55.7	55.9	60.4	61.8
NO_3 (mg/L)	29	18	12	9.3
Po_4^{-3} (mg/L)	20.4	18.6	14.5	12
PH	7.61	7.5	7.64	7.58
Color of sample	gray	Light turbidity	brown	ellowish brow

Test Number / 2/	Date of Test			
	Input	Output _ 1	Output _ 2	Output _ 3
Test time / 11:00 am /	18/12/2023	19/12/2023	24/12/2023	2/1/2024
BOD_5 (mg/L)	440	400	320	200
COD (mg/L)	500	514	520	533
TSS (mg/L)	417	400	423	438
NH_3 (mg/L)	56.7	57	66.4	67
$N\text{-}NH_3$ (mg/L)	46	46.5	54	54.6
NH_4^+ (mg/L)	60.3	60.7	70.5	71.2
NO_3 (mg/L)	26	24.3	14	8
Po_4^{-3} (mg/L)	18	14.2	11.2	6.3
PH	7.41	7.17	7.33	7.48
Color of sample	gray	Light turbidity	brown	ellowish brow

Test Number / 1 /	Date of Test			
	Input	Output _ 1	Output _ 2	Output _ 3
Test time / 11:00 am /	20/11/2023	22/11/2023	26/11/2023	30/11/2023
BOD_5 (mg/L)	300	240	205	165
COD (mg/L)	384	370	377	394
TSS (mg/L)	285	215	283	337
NH_3 (mg/L)	47.7	48.8	62.5	54
$N\text{-}NH_3$ (mg/L)	39.1	39.8	42.6	44
NH_4^+ (mg/L)	50.7	51.9	55.7	57.3
NO_3 (mg/L)	25	18	11.5	8.2
Po_4^{-3} (mg/L)	18.8	13.4	9.4	7
PH	7.5	7.55	7.42	7.48
Color of sample	gray	Light turbidity	Light Brown	ellowish brown

Test Number / 4 /	Date of Test			
	Input	Output _ 1	Output _ 2	Output _ 3
Test time / 11:00 am /	21/2/2023	22/2/2024	25/2/2024	6/3/2024
BOD_5 (mg/L)	120	100	60	60
COD (mg/L)	179	216	223	284
TSS (mg/L)	98	87	44	133
NH_3 (mg/L)	34.3	34.4	35.4	41.8
$N\text{-}NH_3$ (mg/L)	28.15	28.2	28.8	34.4
NH_4^+ (mg/L)	36.35	36.45	37.55	44.3
NO_3 (mg/L)	21	20.4	15.3	1.8
Po_4^{-3} (mg/L)	12.25	11.25	7.55	4
PH	7.42	7.54	7.4	7.44
Color of sample	gray	Light turbidity	Light Brown	ellowish brow

Figures (22,21,20,19): Results of the laboratory tests.

Evaluation of test results on waste rubber tires sample: By analyzing the previous results, the following points were noted:

- Gradual decrease of BOD values as a result of biodegradation of organic matter.
- A gradual rise in COD values as a result of the degradation of rubber and its interaction with wastewater and the formation of new inorganic compounds of phosphate and iron salts.
- A gradual rise in TSS values as a result of the formation of new undissolved suspended compounds.
- A gradual rise in ammonia and ammonia nitrogen values as a result of the transformation of the absence of nitrification and the transformation of nitrates into the three nitrogen compounds, thus decreasing the concentration of nitrates in the resulting water.
- A gradual decrease of phosphate as a result of its association with the iron contained within the composition of the tires and the formation of an unresolved iron triphosphate salt compound.
- Stability of PH value in the moderate range.
- The color of the raw sample follows the sample collection clock and the daily degree of pollution coming to the station where the turbidity decreases as a result of the presence of the rubber filter, then the color of the sample changes and settles at the yellowish brown indicating the presence of iron and phosphorus compounds formed.

- In the next experimental phase, after the growth of canes in the plant, previous experiments will be applied to the water after determining **the places for sampling, which are:**

  - From the raw wastewater tank.
  - From the distribution tank after the primary Sedimentation basin.
  - From the manholes after each plant treatment basin.

- **The plant will be operated according to two main phases:**

<u>First:</u> Cultivation of canes and for the two types of immersion according to the following:
– Total sewage flooding (runoff).
– No submergence with sewage drip (subsurface runoff).
Thus, we will obtain six alternatives to plant treatment basins (cane plant) according to the material of the filter and the type of flow and then to be compared according to a computer program.

Mixed of Grave&Rubber Filter Flow Water Surface 3	Rubber Filter Flow Water Surface 2	Grave filter Flow Water Surface 1
Mixed of Grave&Rubber Filter Subsurface Flow 6	Rubber Filter Subsurface Flow 5	Grave filter Subsurface Flow 4

Figure (20): Matrix of alternatives.

Second: planting ornamental plants:

After choosing the *best alternative* from the previous six alternatives, the basin corresponding to the best filler material (gravel, rubber, mixed) is planted with ornamental plants and compared with cane to verify the possibility of producing other types of plants in orderto improve the aesthetic views at sewage estuaries and constructed wetlands.

The third stage: It includes analyzing the results, linking them to each other, reaching the results of the research, and developing the necessary recommendations and proposals, according to the following:

1. **Analyze the results and determine the efficiency of treatment** after wetland basins according to the selected operational parameters in the plant basins and the type of runoff.
2. **Preparing a simulation software program** that links the inward organic load and the efficiency of treatment in wetlands, according to local conditions and the proposed research plan.
3. **The economic feasibility study** of the proposed treatment method, and comparing the results with the Syrian Standard No. 2752-2008 on the specifications of treated wastewater for irrigation purposes.
4. **Recommendations and Suggestions:** The use of rubber tires waste as a filler in constructed wetlands can achieve several environmental, economic and hydraulic benefits within plant treatment basins as well as supporting sustainability. These objectives can be summarized in the following points:
   - Waste recycling: Disposing of used tires is an environmental challenge. Using them as a filling material contributes to reducing their accumulation in landfills and reduces the need for traditional disposal methods such as burning or landfilling and the resulting negative environmental effects and visual pollution.
   - Improving the quality of water treatment: Fractionated rubber tires can act as a filler to improve the treatment of wastewater or contaminated water in constructed wetlands, as the passage of water through them contributes to improving the filtration of organic materials and pollutants, especially since the iron wires within the tires contribute significantly to the removal of phosphorus, whose removal is a weakness in traditional constructed wetlands.
   - Sustainability of wetlands and avoiding operational problems: Rubber tires are a strong and durable material capable of resisting decomposition for long periods, which makes them suitable as building materials for constructed wetlands. They can also maintain the stability of the infrastructure and reduce the need for frequent maintenance, especially with regard to the problem of clogging within the filler layers due to sediments and solid pollutants that accompany wastewater.

- Economic efficiency: Compared to other traditional materials such as gravel or sand. The use of waste rubber tires is less expensive, especially if there is an abundance of them in local areas as in our country.
- Improving soil characteristics and producing ornamental plants: Waste tires can contribute to improving soil permeability and aeration, which enhances plant growth and the production of various types of local ornamental plants in addition to the traditional cane used in constructed wetlands, which enhances the contribution of the plant to removing sewage pollutants, increasing the efficiency of constructed wetlands and transforming them into a civilizational landscape, especially at sewage estuaries, river banks, gardens and some special places and centers such as universities, hospitals, hotels, etc.

All these technical, economic and environmental motives make the idea of research have a distinctive character that we should apply in our country to improve the environmental and civilizational aspect regarding the current economic situation. Subsequent scientific and academic research can continue to research how to benefit from this system from the point reached by the research and ways to develop it.

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