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# Exploring the potential of *Orthodillo Chiltoni* in the bioremediation of cellulosic wastes: A study of isopoda efficiency and mechanisms

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## Abstract

Terrestrial isopods are integral to the biodegradation of various waste materials, playing a significant role in nutrient cycling and delivering essential ecosystem services. This study evaluates the potential of Orthodillo chiltoni as a model organism for bioremediation in urban settings, with an emphasis on the degradation of municipal, agricultural, park, and market wastes. To assess the biodegradation efficacy of O. chiltoni, we conducted experiments using a range of waste materials—including potato peels, orange leaves, thyme plants, sawdust, and cardboard—under controlled laboratory conditions that simulated the natural habitat of the species. These conditions were optimized for temperature, humidity, and lighting to ensure the methodological rigor and accuracy of the data obtained. The results indicated that O. chiltoni exhibited significant efficiency in the consumption of the waste materials, with consumption rates quantified at 99.525% for potato peels, 87.15% for orange leaves, 78.225% for sawdust, 66.8% for thyme plants, and 61.6% for cardboard residues. The consumption efficiency per individual isopod was measured at 0.796 mg for potato peels, 0.697 mg for orange leaves, 0.625 mg for sawdust, 0.534 mg for thyme plants, and 0.492 mg for cardboard residues. These findings highlight the considerable bioremediation potential of O. chiltoni, indicating that other terrestrial isopod species may also be effective in the biological treatment of various waste types. Future investigations are warranted to examine the applicability of different isopod species across a range of waste treatment contexts, thereby advancing our knowledge and application of these organisms in environmental remediation strategies.

**Keywords:** Armadillidae, Biodegradations, Bioremediation, Environmental cleaners, Orthodillo Chiltoni, Terrestrial isopods.

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## 1. Introduction

The exploration of isopods in the context of bioremediation of cellulosic wastes has gained traction in recent years, particularly as researchers uncover the intricate relationships between these organisms and their microbial partners. [2] provide a foundational overview of terrestrial isopods in urban environments, highlighting their role as macro-decomposers that significantly contribute to the decomposition of plant detritus and the turnover of nutrients in soil ecosystems. Their findings underscore the adaptability of isopods to varying soil conditions, which is critical for understanding their potential in bioremediation efforts.

The bioremediation of cellulosic wastes using Orthodillo chiltoni, a terrestrial isopod, presents a promising approach to managing urban and agricultural waste. This species has demonstrated high efficiency in consuming various cellulosic materials, with consumption rates reaching 99.525% for potato peels and 87.15% for orange leaves, among others, under controlled laboratory conditions that mimic its natural habitat [3]. This method aligns with broader bioremediation strategies that utilize living organisms to degrade hazardous substances into less toxic forms, a process that is both cost-effective and environmentally friendly [4, 5]. While traditional bioremediation often involves microorganisms like bacteria and fungi to break down cellulose into useful by-products such as protein-enriched fodder and sugar syrups [6] the use of Orthodillo chiltoni offers a novel biological approach that could complement these methods. The enzymatic activity of microorganisms, such as those from the genera Brucella, Pseudomonas, and Trichoderma, has been extensively studied for cellulose degradation, highlighting the potential for integrating isopods into existing bioremediation frameworks to enhance efficiency and sustainability [7]. This integration could address the significant environmental challenge posed by the vast amounts of cellulosic waste generated globally, offering a viable solution for waste management and pollution reduction.

Given the escalating issue of solid and cellulosic waste in various environments, combined with the reliance on traditional treatment methods such as burning or open disposal, there are significant health, economic, and environmental repercussions. These practices adversely affect human development while detracting from the aesthetic appeal of cities and rural landscapes [8].

Consequently, this paper aims to identify alternative and safe methods for waste treatment that also safeguard the ecosystem. One promising approach is bioremediation, a branch of biotechnology that utilizes living organisms, including microorganisms and microbial or plant enzymes, to degrade environmental pollutants [9]. For instance, a study demonstrated the successful removal of heavy metals such as zinc, chromium, and nickel from industrial wastewater using banana peels [10]. Numerous studies have also focused on the role of bacteria in bioremediation; for example, Klebsiella pneumonia has been employed to remediate gasoline-contaminated soils [11]. Additionally, this bacterium has been effective in the bioremediation of water contaminated with heavy crude oil [12].

In the present study, has been focused on isopods as they play an affective role in bioremediation processes by consuming and biodegrading various wastes, isopods. are widely distributed, as they are found in various environments, including forests, farms and waste heaps [13] they prefer to live under stones, between cracks and inside cardboard boxes, they enter deep into the soil in the summer because of their constant need for moisture [14].

Isopods have a great importance in knowing the percentage of salinity in agricultural lands, as it has been observed that the soils in which isopods abound were more fertile than others [15] salinity has an impact on the growth and development of many crustaceans [16] many organisms such as plants have been used as bioindicator of air pollution [17] in addition isopods are bioindicator of environmental pollution with heavy metals [18].

The family Armadillidiidae, belonging to the order Isopoda, is one of the most widespread groups of terrestrial isopods, with notable populations found in Asia, North Africa, Australia, Mexico, and the United States [19]. Members of this family play a vital role in enhancing nutrient cycling within soils, promoting the decomposition of organic matter, and facilitating the production of essential nutrients such as phosphates and nitrogen compounds necessary for plant growth [20]. Armadillidiidae is among the most significant groups of soil invertebrates, utilizing their natural processes to benefit both the environment and other living organisms [21]. These isopods exhibit high population densities, ranging from 880 individuals per square meter in May to 251 individuals per square meter in January, along with a marked tendency for aggregation in the studied areas [22]. Given these characteristics, this study was designed to evaluate the efficiency of Orthodillo chiltoni Vandel [1] in consuming various cellulosic wastes, highlighting its potential as an environmental cleaner.

## 2. Materials and Methods

*2.1. Samples Collection*

Samples of the species O. chiltoni Vandel [1] studied were collected from agricultural fields and parks of Babylon, Fig (1),potato farms of Nineveh and citrus orchards of Diyala provinces, small soil digging tools, tweezers and brushes were used, placed after collection in plastic containers with dewy field soil and transported to the laboratory, the individuals of this species were diagnosed and bred by using what the researchers reported [23-25].

**Figure 1.**
Environment of *O. chiltoni* Vandel [1].

*2.2. Preparing Permanent Farms*

Permanent farms of individuals of the species O. chiltoni Vandel [1] were prepared by taking 25-liter containers, which were spread with a layer of agricultural soil with a good organic content at a depth of layer of dry plant leaves was added to it, after being washed and dried them to get rid of the toxins and pollutants suspended in them, such as the residues of the pesticides and because they were used as a medium food for individuals of the species [26] the medium was moistened several times during the day, the adults were left to breed between 4-5 weeks until the first generation individuals were obtained, they were left. until the six-month age were separated from the rest of the individuals, and experiments were conducted on them to evaluate their ability to consume and decompose various cellulosic wastes.

*2.3. Consumption Efficiency Test*

Quantities of five types of cellulosic waste were collected from various environments: household sources such as potato peels, agricultural fields like orange leaves, urban areas represented by sawdust, park residues such as thyme plant remnants, and market waste including cardboard. The materials were washed several times to remove environmental toxins and dust, then dried and cut into small pieces. A total of 40 g of each type of waste was used as food for individuals of the species O. chiltoni Vandel [1] with five replications. Clean large glass Petri dishes were prepared with large filter papers placed at the bottom to maintain continuous hydration. Water drops were added to introduce moisture into the dishes, and 8 g of each type of waste was added separately. Six-month-old individuals were included in the experiments to assess the efficiency of young isopods in consuming waste, with 10 individuals per dish. The samples were placed inside plastic boxes covered with black cloth to create an artificial environment similar to their natural habitat. At the end of the experiment, the isopods were removed, and the remaining waste was collected and allowed to dry completely. The remaining weight was recorded, and the consumed weight was calculated by subtracting the remaining weight from the original weight [27]. The average consumption over the five replications was recorded over a 15-day period, as shown in the results.

- Temperature measurements were obtained using a digital thermometer, yielding an average temperature range of 22 to 25 °C. Additionally, average relative humidity was recorded at 70% utilizing a thermograph of the type "relative humidity-dinlex."

## 3. Results

Table 1 has shown that individuals of the species O. chiltoni Vandel [1] recorded different results in consuming cellulosic wastes, as the average total consumption of orange leaves was 34.86 g, all reading for the five replicates was recorded similar results in consumption, as they fell between 6.99 g as the highest value and 6.95 g as the lowest value.

**Table 1.**
Consumption efficiency of individual ***O. chiltoni*** at six months age for orange leaves.

| Sample | Number of individuals | Wastes weight before consumption /g | Consumed weight /g | Remaining weight/g |
|---|---|---|---|---|
| 1 | 10 | 8 | 6.97 | 1.03 |
| 2 | 10 | 8 | 6.97 | 1.03 |
| 3 | 10 | 8 | 6.99 | 1.01 |
| 4 | 10 | 8 | 6.95 | 1.05 |
| 5 | 10 | 8 | 6.98 | 1.02 |
| Total | 50 | 40 | 34.86 | 5.14 |

**Table 2.**
Consumption efficiency of individual ***O. chiltoni*** at six months age for sawdust wastes.

| Sample | Number of individuals | Wastes weight before consumption /g | Consumed weight/ g | Remaining weight/g |
|---|---|---|---|---|
| 1 | 10 | 8 | 6.29 | 1.71 |
| 2 | 10 | 8 | 6.24 | 1.76 |
| 3 | 10 | 8 | 6.27 | 1.73 |
| 4 | 10 | 8 | 6.24 | 1.76 |
| Total | 50 | 40 | 31.29 | 8.17 |

From Table 3 it became clear that the consumption efficiency of the individuals of this species was very high for the potato peels wastes, as the total consumption average reached 39.81g of the total wastes weight, which was 40g, and consumption values ranged the between 7.99g as the highest value and 7.93g as the lowest value.

**Table 3.**
Consumption efficiency of individual ***O. chiltoni*** at six months age for potato peels wastes.

| Sample | Number of individuals | Wastes weight before consumption /g | Consumed weight/ g | Remaining weight/g |
|---|---|---|---|---|
| 1 | 10 | 8 | 7.99 | 0.01 |
| 2 | 10 | 8 | 7.95 | 0.05 |
| 3 | 10 | 8 | 7.97 | 0.03 |
| 4 | 10 | 8 | 7.97 | 0.03 |
| 5 | 10 | 8 | 7.93 | 0.07 |
| Total | 50 | 40 | 39.81 | 0.19 |

The results have shown that the average total consumption of the thyme plant wastes was 26.72g, as shown in Table 4 and the highest consumption value was 5.36 g and the lowest value was 5. 31g.

**Table 4.**
Consumption efficiency of individual ***O. chiltoni*** at six months age for thyme plant wastes.

| Sample | Number of individuals | Wastes weight before consumption /g | Consumed weight/g | Remaining weight /g |
|---|---|---|---|---|
| 1 | 10 | 8 | 5.36 | 2.64 |
| 2 | 10 | 8 | 5.34 | 2.66 |
| 3 | 10 | 8 | 5.31 | 2.69 |
| 4 | 10 | 8 | 5.35 | 2.65 |
| 5 | 10 | 8 | 5.36 | 2.64 |
| Total | 50 | 40 | 26.72 | 13.28 |

As for cardboard wastes, the highest consumption value was 4.96g and the lowest value was 4.90g, while the total consumption average was 24.64g out of the total wastes weight of 40g, as shown in Table 5.

**Table 5.**
Consumption efficiency of individual ***O. chiltoni*** at six months age for cardboard wastes.

| Sample | Number of individuals | Wastes weight before consumption /g | Consumed weight/g | Remaining weight/g |
|---|---|---|---|---|
| 1 | 10 | 8 | 4.90 | 3.10 |
| 2 | 10 | 8 | 4.96 | 3.04 |
| 3 | 10 | 8 | 4.93 | 3.07 |
| 4 | 10 | 8 | 4.90 | 3.10 |
| 5 | 10 | 8 | 4.95 | 3.05 |
| Total | 50 | 40 | 24.64 | 15.36 |

And from calculated the efficiency of one individuals of terrestrial isopods to consume the five cellulosic wastes, it was found that they proceeded in the same order, as the highest efficiency was to consume potato peels which amounted to 0.796g and then the rest of the wastes came from orange leaves, sawdust, thyme plant cardboard, respectively with values 0.697,0.625,0.534 and 0.492mg, as shown in Table 6.

**Table 6.**
The per capita consumption efficiency and percentage of total consumption of O. ***chiltoni*** at six months for various cellulosic wastes.

| Type of cellulosic waste | Number of individuals | Total weight of waste before consumption /g | Total consumption/g | Per capita consumption efficiency/mg | Percentage of total consumption |
|---|---|---|---|---|---|
| orange leaves | 50 | 40 | 34.86 | 0.6972 | 87.15% |
| sawdust | 50 | 40 | 31.29 | 0.6258 | 78.225% |
| potato peels | 50 | 40 | 39.81 | 0.7962 | 99.525% |
| thyme plant | 50 | 40 | 26.72 | 0.5344 | 66.8% |
| cardboard | 50 | 40 | 24.64 | 0.4928 | 61.6% |

Figures 2 and 3 have shown the percentage of total consumption and the efficiency of consumption per capita, we have found that the consumption of potato peels wastes came in the first grade and recorded the highest percentage amounted 99.52%, followed by orange leaves, saw dust, thyme plant and cardboard, the percentage amounted 87.15% , 78,22%, 66.8% and 61.6 % respectively .Significant differences were recorded at the level 0.01 and 0.05 according to the Anova statistical program.

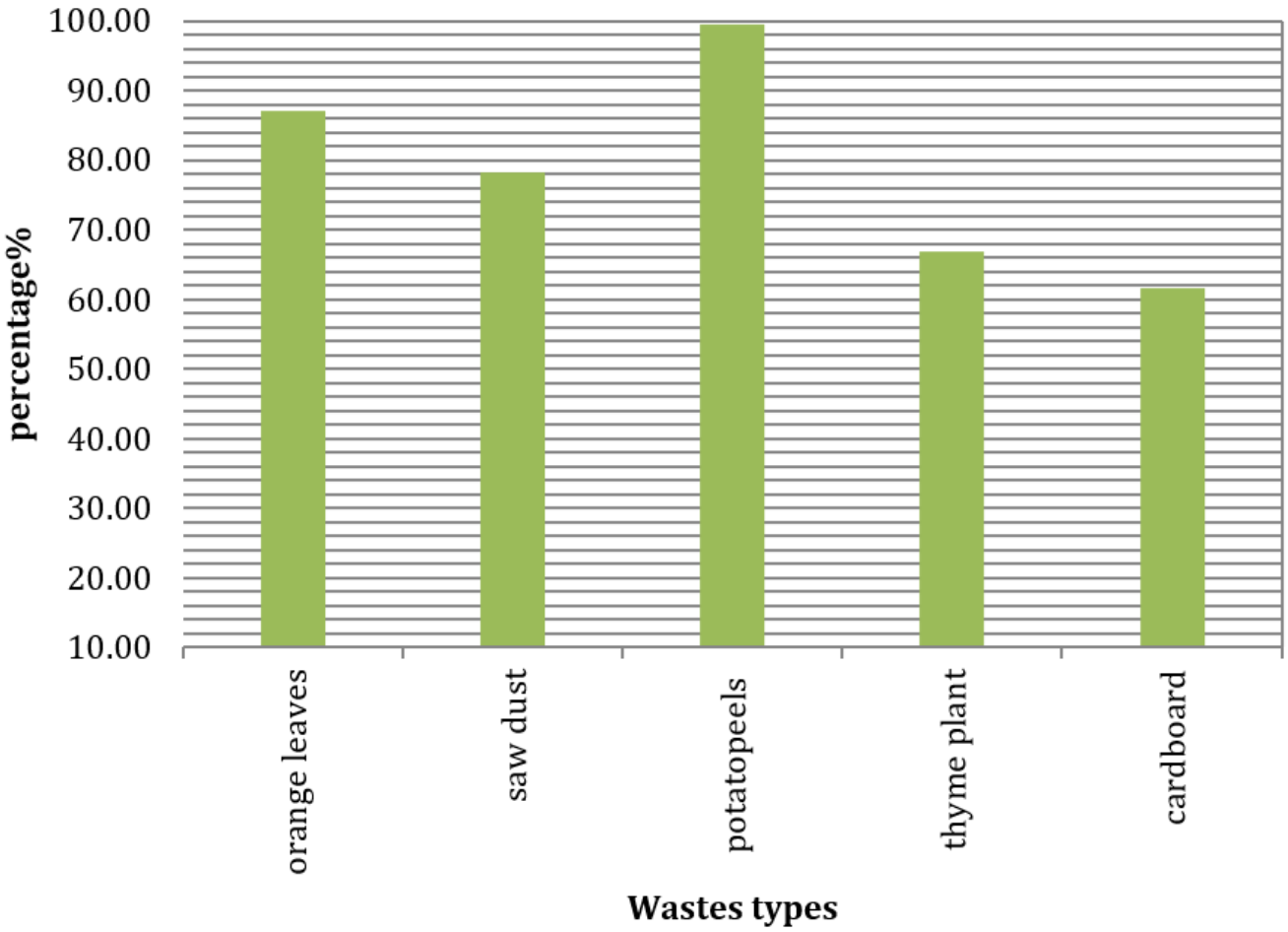


**Figure 2.**
Percentage of the total consumption of individuals *O. chiltoni* at six months age for various cellulosic wastes.

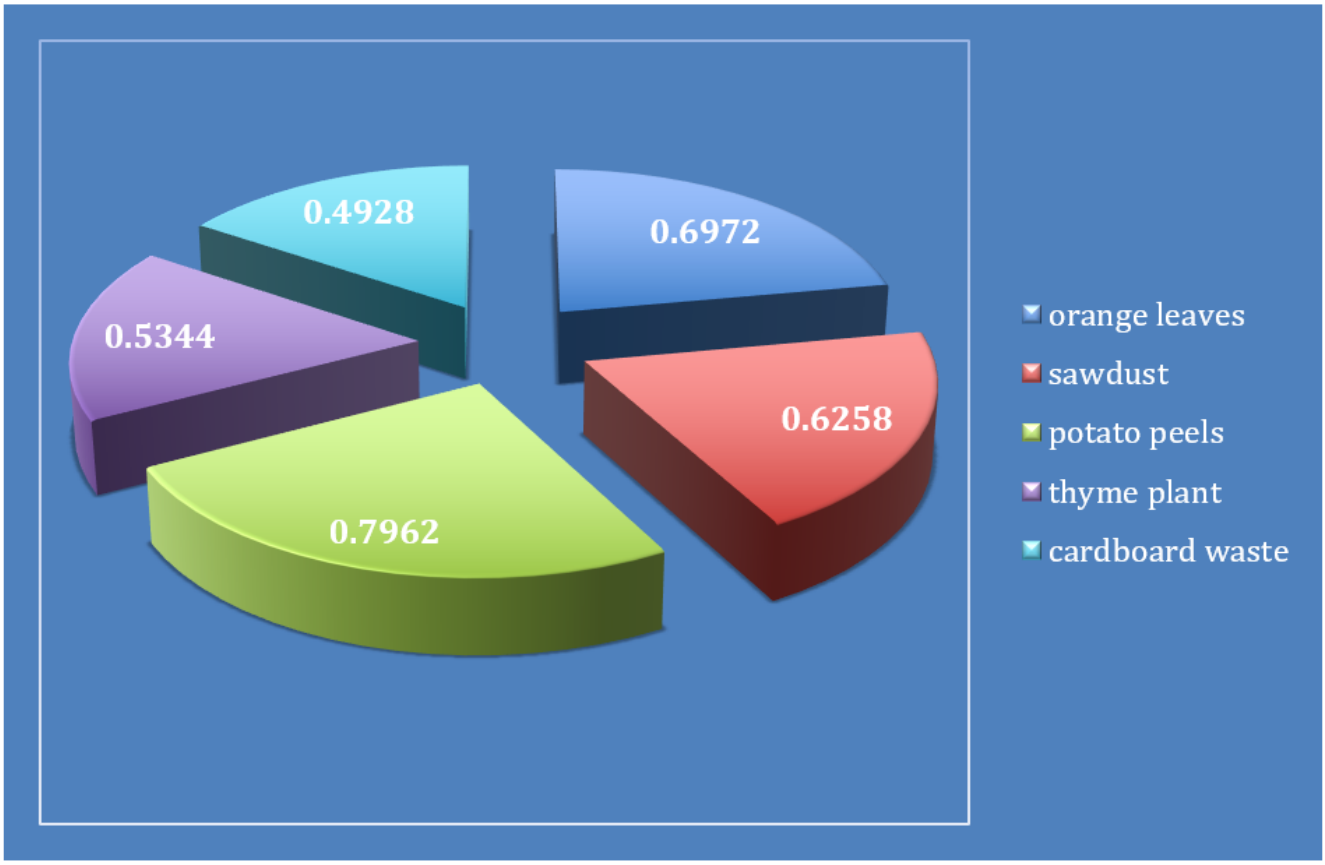


**Figure 3.**
Per capita consumption efficiency of *O. chiltoni* at six months age for various cellulosic wastes.

## 4. Discussion

Orthodillo chiltoni, a terrestrial isopod, has demonstrated significant efficiency in consuming various cellulosic wastes, including orange leaves. In a study examining its bioremediation potential, O. chiltoni individuals consumed 87.15% of orange leaves, with each isopod consuming an average of 0.697 mg of these leaves [3]. This consumption rate highlights the species' capability to contribute to the biodegradation of cellulosic materials, which is crucial for nutrient cycling and ecosystem services. The efficiency of O. chiltoni in processing orange leaves is comparable to that of Porcellionides cingendus, another isopod species, which consumed 81.9% of citrus leaves in a separate study [3].

When followed up table (2) the values were found to range between 6.29 g as the highest value and 6.24 g the lowest as value, and the average total consumption of sawdust was 31.29g out of the total wastes weight of 40g, likewise the consumption efficiency of individuals of this species was similar in all samples. While sawdust is also utilized in other applications, such as a component in concrete to improve thermal properties and as an absorbent in wastewater treatment, its role in bioremediation through isopods presents a sustainable waste management strategy [28, 29]. The use of sawdust in these diverse applications underscores its versatility and the importance of optimizing its utilization to reduce environmental impact and enhance resource efficiency [30, 31]. The study of O. chiltoni's consumption efficiency thus contributes to a broader understanding of sustainable practices in waste management and resource utilization.

The consumption efficiency of individual O. chiltoni at six months of age for thyme plant wastes is not directly addressed in the provided papers. However, insights can be drawn from related studies on thyme's nutritional and functional properties. Thyme essential oil has been shown to enhance nutrient digestibility and growth performance in Ossimi lambs, suggesting potential benefits in animal feed applications [32] additionally, thyme waste, which contains bioactive compounds such as benzoic and ferulic acids, has demonstrated antioxidant properties in oil-in-water emulsions, indicating its potential as a valuable feed additive [33].

The results have been demonstrated that individuals of this species are efficient in consuming cellulosic wastes, and this is due to the structure of their digestive system as, cellulose was digested and analyzed in the interior mid gut, and this is done with the help of symbiotic bacteria present in hepatopancreatic glands [34, 35].

Orthodillo chiltoni Vandel [1] a species of terrestrial isopod, has demonstrated a significant attraction to potato peel wastes, as evidenced by its high consumption rate in controlled experiments. In a study focusing on the bioremediation potential of O. chiltoni, it was found that individuals of this species consumed 99.525% of potato peels, indicating a strong preference and efficiency in processing this type of waste compared to other materials like orange leaves and sawdust [3]. This high consumption rate suggests that potato peels are particularly appealing to O. chiltoni, possibly due to their chemical composition or nutritional content. While the specific volatile organic compounds (VOCs) emitted by potato peels that might attract O. chiltoni were not directly studied in the provided contexts, it is known that potato tubers emit VOCs that are attractive to other soil organisms, such as wireworms [36]. This implies that similar compounds could potentially

influence the foraging behavior of isopods. Additionally, the role of volatiles in mediating interactions between soil invertebrates and their food sources is well documented, with certain volatiles acting as attractants and phagostimulants for isopods [37, 38]. Therefore, the attraction of O. chiltoni to potato peels could be partially attributed to the presence of such volatiles, enhancing their role in waste decomposition and nutrient cycling in ecosystems

## 5. Conclusions

The analysis indicates that Orthodillo chiltoni Vandel [1] exhibits remarkable efficiency in consuming various cellulosic wastes, suggesting its utility in bioremediation at landfill and waste accumulation sites under suitable conditions. Consideration of factors such as isopod age and numerical density is essential for optimizing results in both laboratory and practical settings.

Given its efficacy, O. chiltoni represents a potent environmental cleaner that can address diverse waste types without traditional treatment methods, highlighting its potential for innovative waste management strategies. Future research should focus on optimizing conditions to enhance waste consumption efficiency of O. chiltoni and investigate the application of other terrestrial isopod species for bioremediation, promoting sustainable waste management practices. These findings underscore the significance of biological approaches in waste treatment as a viable alternative to conventional methods, contributing to more sustainable and environmentally friendly waste management solutions.

## References


[1] A. Vandel, "Terrestrial isopods (Oniscidea) of Melanesia," *Zoologische Verhandelingen*, vol. 125, pp. 1–160, 1973.

[2] K. Szlavecz, F. Vilisics, Z. Tóth, and E. Hornung, "Terrestrial isopods in urban environments: An overview," *ZooKeys*, no. 801, pp. 97-106, 2018. https://doi.org/10.3897/ZOOKEYS.801.29580.

[3] Z. H. Salman and I. M. Alsalman, "Bioremediation of cellulosic wastes by using orthodillo chiltoni (Vandel, 1973), Isopoda," 2024. https://doi.org/10.21203/rs.3.rs-3927749/v1

[4] J. C., B. C., and S. C., "Bioremediation," pp. 1-20, 2023.

[5] T. N. Khan, "Bioremediation—an effective cleanup technology," *Environmental Science: An Indian Journal*, 2018.

[6] A. El Nawawy, E. El-Rayes, R. Al Hussaini, and A. Tawheed, "Bioconversion of cellulosic wastes," *Perspectives in Biotechnology and Applied Microbiology*, pp. 223-230, 1986. https://doi.org/10.1007/978-94-009-4321-6_16

[7] A. Kavimandan and A. Pethe, "Production of biocompost by cellulosic waste," *International Journal of Applied Research*, vol. 2, no. 7, pp. 368-370, 2016.

[8] B. F. Derge and Z. G. Bijem, "Management of solid waste in West Asia," *Journal of Agricultural Engineering Research*, vol. 70, pp. 478-483, 2017.

[9] H. I. Smith, O. T. Riddey, and L. M. Parmen, "Potential biotechnological strategies for the cleanup of soil contamination in Southern Zambia," *Journal of African Biology and Technology*, vol. 5, no. 1, pp. 621-632, 2022.

[10] M. Al-Azzawi, S. Shartooh, and S. Al-Hiyaly, "The removal of zinc, chromium and nickel from industerial waste-water using banana peels," *Iraqi Journal of Science*, vol. 54, no. 1, pp. 72-81, 2013.

[11] R. A. A.-H. Neif and I. K. A. Al-Mayaly, "Biodegradation of aromatic and alkanes compounds in contamination soils with gasoline by Klebsiella pneumoniae," *Iraqi Journal of Science*, vol. 56, no. 3C, pp. 2574-2584, 2015.

[12] A. W. Ahmed, F. S. Alzubaidi, and S. J. Hamza, "Biodegradation of crude oil in contaminated water by local isolates of Enterobacter cloacae," *Iraqi Journal of Science*, vol. 55, no. 3, pp. 1025-1033, 2014.

[13] X. L. Beng and F. Ozer, "Fossil isopods and the evolution of terrestrial isopods (Crustacea: Oniscidea)," *Muzunami Fossil Mus*, vol. 44, no. 5, pp. 12-19, 2010.

[14] I. C. Friedrich and N. E. Jan, "Biodegradation of terrestrial Isopods in soil," *Journal of Crustaceana*, vol. 5, pp. 66-73, 1988.

[15] O. Z. Aild, M. L. Wynne, and S. E. Zhang, "Phylogenetic analysis of the isopoda with some classification from Southern Spain," *Journal of Biological Reviews*, vol. 68, no. 2, pp. 233-239, 2007.

[16] H. J. Jware and N. I. T. Al-Ameen, "Effect of salinity on survival, development and growth of Artemia sp," *Baghdad Science Journal*, vol. 6, no. 4, pp. 621-626, 2009.

[17] W. A. AlObaidy and A. M. Rabee, "Use citrus aurantium plant as bio-indicator of air pollution in Baghdad city," *Iraqi Journal of Science*, pp. 824-831, 2018.

[18] M. Barnoz, "Bioremediation of soil contaminated with cadmium," *Journal of Environmental Pollution*, vol. 97, no. 4, pp. 868-877, 2001.

[19] H. R. Eumer, "Morphology and biogeography of the family armadillidae," *Journal of Natural History*, vol. 43, pp. 802-809, 2004.

[20] R. T. Aramo, "Nutrition in terrestrial isopods (Isopoda: Armadillidae) approaches," *Bulletin of Biology*, vol. 72, no. 1, pp. 488-495, 1998.

[21] P. W. Hass and E. M. Jehan, "The flow coblet through a terrestrial isopod food chain," *Journal of Evolutionary Biology of Land Isopods*, vol. 64, no. 2, pp. 255-264, 1968.

[22] I. M. Jasim, Y. T. Daoud, and H. J. Jaweir, "Population dynamics of the terrestrial isopod species armadillidium vulgare latreille, 1804 in Al-Jadriyia District, Baghdad, Iraq," *Journal of Baghdad Science*, vol. 8, no. 1, pp. 453-461, 2011.

[23] S. T. Gole, "The interaction between terrestrial isopods armadillidium (Brandt, 1833) of Bermuda," *Journal of Historical Biology*, vol. 77, pp. 191-198, 1975.

[24] O. L. Demson, E. P. Kawart, and C. T. Buchelos, "Linkage of biomarkers along levels of isopoda, armadillindium vulgare," *Journal of Environmental Toxicity and Chemistry*, vol. 22, no. 1, pp. 85-91, 1993.

[25] H. Biveter, "The ecology of paleozoic terrestrial isopods," *Journal of Geological Society of India*, vol. 81, no. 3, pp. 91-99, 2016.

[26] N. D. Canovai, "New record of saw bug (Crustacea: Isopoda) from Resin in Italy," *Journal of Coastal Society of Earth*, vol. 19, no. 2, pp. 30-37, 2009.

[27] I. M. A. Al-Salman, "Testing the ability of porcellionides prusinosus (Brandt, 1833) isopoda crustaceans to decompose and consume cellulose wastes in different ecosystems," *Journal of Baghdad Science*, vol. 9, no. 3, pp. 397-405, 2012.

[28] H. F. Gassan *et al.*, "Mechanical, thermal and durable performance of wastes sawdust as coarse aggregate replacement in conventional concrete," *Jurnal Teknologi (Sciences & Engineering)*, vol. 81, no. 1, 2019. https://doi.org/10.11113/JT.V81.12774

[29] H. Majid, G. Y. Al Kindi, and J. K. Al Refaaec, "A sawdust filter is used to remove oil from the kitchen wastewater," presented at the In IOP Conference Series: Earth and Environmental Science (Vol. 1120, No. 1, p. 012028). IOP Publishing. https://doi.org/10.1088/1755-1315/1120/1/012028, 2022.

[30] A. A. Rilly and U. S. Minaka, "Analysis of the effect of sawdust as fine aggregate additive on concrete compressive strength," *Fondasi: Jurnal Teknik Sipil*, vol. 11, no. 2, pp. 210-218, 2022. https://doi.org/10.36055/fondasi.v11i2.16745

[31] G. O. Opharuomaghua, "Efficiency of wood wastes as alternative energy sources to fuel wood in fish smoking in view to optimize the utilization of wood resources," 2017.

[32] S. El-Naggar, G. Abou-Ward, M. Tawila, F. Helal, and A. Ali, "Performance of lambs fed rations supplemented with thyme essential oil," *Egyptian Journal of Nutrition and Feeds*, vol. 20, no. 2, pp. 189-195, 2017. https://doi.org/10.21608/EJNF.2017.75165

[33] S. El-Guendouz *et al.*, "Antioxidant activity of thyme waste extract in O/W emulsions," *Antioxidants*, vol. 8, no. 8, p. 243, 2019. https://doi.org/10.3390/ANTIOX8080243

[34] D. F. Humason, "Effect of terrestrial isopods on soil waste dissociation," *Journal of Applied Zoology*, vol. 45, pp. 15-23, 2013.

[35] G. A. John, F. M. T. Thomas, and T. M. Kent, "Solid waste management in agricultural soils of Panama," *International Journal of Environmental Research*, vol. 22, pp. 69-78, 2020.

[36] D. La Forgia and F. Verheggen, "The law of attraction: Identification of volatiles organic compound emitted by potatoes as wireworm attractants," *Communications in Agricultural and Applied Biological Sciences*, 2017.

[37] K. C. Cannon, "Volatile-mediated arthropod-fungus interactions," 2022. https://doi.org/10.53846/goediss-7248

[38] M. Petre, G. Zarnea, P. Adrian, and E. Gheorghiu, "Biodegradation and bioconversion of cellulose wastes using bacterial and fungal cells immobilized in radiopolymerized hydrogels," *Resources, Conservation and Recycling*, vol. 27, no. 4, pp. 309-332, 1999. https://doi.org/10.1016/S0921-3449(99)00028-2