environments

Review

A Comprehensive Review of Risk Assessments of Organic Effluents in Car Workshops

Rémi Bouchiat [1,2], Etienne Veignie [2], Fabien Kaczmarek [1], Julien Dorchy [1], Anne-Danièle Fortunato [1] and Catherine Rafin [2,*]

[1] Norauto, 2A Boulevard Van Gogh, 59650 Villeneuve-d'Ascq, France; rbouchiat@norauto.com (R.B.)
[2] Unité de Chimie Environnementale et Interactions sur le Vivant UCEIV, UR4492, Université du Littoral Côte d'Opale, 59140 Dunkerque, France; etienne.veignie@univ-littoral.fr
* Correspondence: rafin@univ-littoral.fr

Abstract: Water is an essential resource for the functioning of society, where it is involved in key areas such as domestic use, agriculture, energy production, industry, and transport. Climate change exacerbates water scarcity. In the context of preserving water resources, effluents from the automobile sector need to be deeply considered due to their environmental impacts. This review focuses especially on the water effluents generated by car workshops. In car workshops, daily floor washing waters containing organic pollutants, either from vehicle components or from products used for maintenance and repair, can represent large volumes of water (between 15 L and 50 L per day) that are discharged into the wastewater system. These particular industrial organic effluents are not well characterized and can represent severe environmental risks. The aim of this review is to help automotive maintenance and repair professionals better manage these industrial organic effluents. We first describe the potential sources of organic pollution emissions in car workshops with the purpose of identifying the organic compounds to be monitored as a priority in the wash water. Then, we apply a risk prevention management tool, based on the criticality matrix, to identify products with a high risk of leaking onto the ground in order to limit organic pollutants at the source.

Keywords: organic pollutants; criticality matrix; risk prevention; industrial water management

Citation: Bouchiat, R.; Veignie, E.; Kaczmarek, F.; Dorchy, J.; Fortunato, A.-D.; Rafin, C. A Comprehensive Review of Risk Assessments of Organic Effluents in Car Workshops. *Environments* **2023**, *10*, 220. https://doi.org/10.3390/environments10120220

Academic Editor: Simeone Chianese

Received: 10 October 2023
Revised: 29 November 2023
Accepted: 1 December 2023
Published: 13 December 2023

1. Introduction

The water crisis is currently the most worrying global issue. The growing concern about water scarcity is linked to demand due to rapid population growth, urbanization, and economic development. Climate change exacerbates water scarcity. Earth has a finite quantity of water, estimated at more than 1 billion km^3. However, the fresh water available for human societal use is estimated to be 0.7% of the global terrestrial quantity. Therefore, the challenge for the years to come is to preserve this resource in view of the reduction in freshwater reserves due to climate change.

In this review, we focus on the organic effluents generated by car workshops and the environmental impacts of such activities. In the automobile sector, the most studied effluents are those produced from car traffic that leach into road waters [1–3], and particular attention has been paid to the issue of microplastics, alkylphenols, polycyclic aromatic hydrocarbons (PAHs), and heavy metals entering water sources. Car wash activities and their effects on water reuse are another well-studied aspect of the automobile sector [4,5]. In comparison, effluents resulting from automobile maintenance activities and repairs are seldom studied. However, this activity is highly important in the automotive sector because of its globalization, its persistence from the time the vehicle exits the factory to the end of its life, and the frequent absence of water pre-treatment systems in workshops in many areas around the world. In Europe, since 2000, the Water Framework Directive (WFD) has focused on ensuring good qualitative and quantitative health outcomes by reducing the generation of pollution, removing pollution, and ensuring that the quantity and quality of water resources are sufficient to meet human needs and environmental demands [6]. In the context of preserving water resources, it seems necessary for automobile repair and maintenance professionals to manage the effluents from automobile workshops more effectively.

By offering many services, such as oil and tire changes as well as brake, transmission, distribution, cooling, and exhaust system maintenance, car workshops produce specific industrial effluents that are mainly concentrated in workshop floor washing waters. These effluents consist of a complex mixture of residues containing compounds contributed by the car and its parts or by the activities of car maintenance and repair. Based on our current knowledge, these effluents, which are mainly composed of organic compounds, have been understudied. They must be taken into consideration in terms of their environmental impact according to the WFD objectives, especially as pre-treatment solutions for washing water are often neglected by car workshops.

The aim of this paper is to review the principal services offered in a car workshop and identify the main organic compounds to monitor in wash water by specifying their physical and chemical properties. Then, we detail a risk prevention tool, based on the criticality matrix, to help automobile professionals identify potential pollution sources and therefore limit the spillage of products used for vehicle maintenance and repair. As far as we know, this approach, which combines a bibliographical study with the design of a criticality matrix, is innovative in this sector. It could facilitate the complex implementation of an environmental risk management plan for automobile workshops by offering an easy-to-use tool to reduce the release of organic pollutants into the environment.

2. Services Carried Out in Automobile Workshops and Sources of Organic Pollution

2.1. Tire Changing and Shear Stresses with the Floor

Changing tires is a service carried out daily in automobile workshops and involves several stages: the dismantling of the wheel, which can release particles accumulated during the operation of the vehicle; the handling of used and new tires on the floor; fitting the new tire; and rim cleaning. In car tires, the tread, which is the only layer in contact with the ground, is made of a mixture of natural rubber derived from *Hevea brasiliensis* (Euphorbiaceae) and petroleum-based synthetic polymers [7]. Pollutants emitted during this service depend on the state of the tire (new or used). Shear stresses exerted on the tread in contact with the road are responsible for tire wear, producing particles that are potentially released into the environment ranging from 0.001 µm to more than 100 µm [8] and with physicochemical properties distinct from those of the original tread. The modification of the emitted particles results from the friction between the tire and the ground surface due to the heat produced during this contact or due to the integration of material particles present on the road [9]. All these particles can then be deposited on the workshop floor during vehicle circulation or tire handling. The carbon compounds identified in these particles are composed of 88% organic substances, 4% elementary carbon (mostly identified as carbon black that is used to reinforce the tire [10]), and 8% carbonated products [8]. A study carried out by Rogge and his team focused on the characterization of organic substances released by thermal vehicle constituents [10]. The authors mainly identified alkanes with carbon chains between C19 and C41, among which heptatriacontane (C37) had the highest concentration (2301 µg g^{-1}). These alkanes are constituents of paraffins, serving as protective agents against ozone and ultraviolet rays to prevent premature tire wear during storage [10]. The other substances include carboxylic fatty acids, mainly represented by stearic acid and palmitic acid, natural resins, and benzothiazole. The last family of compounds found is that of PAHs, representing 200 µg g^{-1} of tire particles and mainly including pyrene, fluoranthene, and phenanthrene. They are used as extender oils to provide tread elasticity, or they are contaminants of carbon black. Since January 2010, extender oils used for tire production have been regulated by the European Commission

(EC), which prohibits extenders containing more than 1 mg kg^{-1} of benzo(a)pyrene and 10 mg kg^{-1} total of all PAHs listed in this directive [11].

Therefore, various chemical compounds could be deposited on the workshop floor due to the vehicle's circulation and tire handling, making it likely that a variety of organic compounds could be identified on the ground, in particular alkanes and PAHs, in addition to the exogenous particles accumulated on tires prior to their entry into the workshops.

2.2. Braking System Servicing

Another source of organic compounds found on the workshop floor is the release of fine particles, between 0.1 µm and 10 µm in size, that accumulate in wheels during vehicle braking. The braking system consists of the brake disc, made of inorganic compounds, and the brake pads, which contain organic products in the form of resin, carbon fibers, and graphite [12]. Wahlström and his team investigated the size, shape, and elemental composition of airborne wear particles collected on filters in tests conducted in a disc brake assembly test stand [12]. Both the low-metallic and non-asbestos organic type of brake pads displayed a bimodal size distribution with peaks at 280 and 350 nm. Most of the airborne particles generated had a diameter smaller than 2.5 µm and could therefore be classified as particular matter PM2.5, i.e., particles with aerodynamic diameters less than 2.5 µm, which is a category established by the EC and by the US Environmental Protection Agency (USEPA). By studying the release of fine particles from seven different brake pads fitted to light-duty vehicles with a dynamometer, it was shown that 35% of the brake particles were produced in the form of fine particles in the environment, of which 18% were carbonaceous particulate matter [13]. The GC-MS analysis of the organic fraction showed a respective concentration, expressed in µg g^{-1}, of 38 n-alkanes, 540 alkanoic acids, 34 alcohols, 19 substituted benzaldehydes, 879 polyalkylene glycol ethers, and 16 PAHs [10]. The PM10 organic fraction showed that the mass of the carbonaceous fraction varied between 5.07 and 75.4% and contained more than 150 organic compounds, including C11 to C33 n-alkanes (4.54–68.1 mg g^{-1} PM10), PAHs with five or fewer benzene rings (3–137 mg g^{-1} PM10), alcohols, different types of acids, glycerol derivatives, polyalkylene glycol ethers, plasticizers, sugars, sterols, and phenolic compounds [14].

To ensure the proper functioning of the braking system, the brake fluid must withstand high temperatures, have good viscosity, be physically and chemically stable, protect the metal parts of the hydraulic circuit against corrosion, not damage the rubber parts of the system, and have lubricating properties. Thus, most brake fluids are mainly composed of glycols with alkylene glycol alkyl ethers (70% to 80%); polyethylene, propylene polyglycol, or borate esters of alkylene glycol alkyl ethers (20% to 30%); and inhibitors like anti-corrosion, anti-oxidation, stabilizing, and anti-foaming additives (5% to 10%) [15].

Therefore, leaks from the hydraulic circuit, or improper handling of brake fluid, can lead to spills on the ground. These spills are likely to occasionally transfer glycol ethers from the brake fluid, as well as brake particles made up mostly of n-alkanes, PAHs, and polyalkylene glycol ethers, to the wash water.

2.3. Fuel and Oil Leaks

One of the failures that can occur in a vehicle is a leak from an injector (the part which carries fuel from the tank to the combustion chamber of the engine) causing fuel to accumulate on the ground. Crude oil shows a complex chemical structure and is mainly composed of three types of hydrocarbons: alkanes, cycloalkanes, and aromatic compounds. Petrol and diesel are commercial petroleum products refined from crude oil with chemical compositions that depend on the nature and conditions of the geological formation of the original oil, particularly for diesel, as well as the methods used for its refinement [16]. Petrol is made up of around 200 different hydrocarbons, of which benzene, toluene, ethylbenzene, and xylene (BTEX) are the most studied [17]. It has only light hydrocarbons, ranging from 4 to 10 carbon atoms [18]. In a commercial 98 unleaded petrol sample studied by Solano-Serena and his team, hydrocarbons of between 6 and 10 carbon atoms predominated in the mixture (64.9%), with the proportion of BTEX equal to 35.7% and methyl and dimethyl alkanes being the most abundant (22.7%) of the C4–C6 compounds [17]. The proportion of aromatic compounds could also reach a higher rate of 50% in the mixture [18]. Diesel has a more complex formulation than petrol. It has between 2000 and 4000 different hydrocarbons, which have carbon chains between 11 and 25 atoms, comprising 46% isoalkanes and cycloalkanes, 30% aromatic compounds, and 24% n-alkanes [18]. Different additives are added to improve the auto-ignition characteristics of diesel [16].

The risk of motor oils spilling on the workshop floor comes from leaks linked to a breakdown of the vehicle, accidental spills during oil changes, or improper storage of used oil. Motor oils are generally made from a mixture of 90% hydrocarbons and 10% additives [19], with the proportion depending on the supplier. The hydrocarbon compounds of motor oils are linear and branched paraffinic or naphthenic chains with more than 15 carbon atoms and aromatic hydrocarbons. This complex mixture confers a good viscosity to the oil and a boiling point between 300 °C and 600 °C [20]. Additives include antioxidants (phenols, amines, and sulfide), anti-foaming agents (silicones), anti-wear agents (fatty acids and organophosphorus esters), dispersants, corrosion inhibitors (fatty acids and their salts, sulfonates), and high-temperature oil viscosity improvers (polyalphaolefin, polymethacrylate, and polyalkylstyrene) [20]. In workshops, the oil collected during an oil change is therefore significantly different from that sold by the supplier due to the transformations it has undergone during the engine combustion process. Therefore, the USEPA has defined used motor oil as petroleum-based or synthetically created oil that has been used in the lubrication of a vehicle and which, under normal conditions of use, has been contaminated by various impurities such as dust, water, chemical compounds, or metals from the vehicle engine [19]. Although the main change in used oil involves its metal concentration, it also has high concentrations of PAHs, whose mutagenic and carcinogenic impacts are known [21].

To summarize, the potential sources of organic pollution in a car workshop mainly come from tires, the braking system, fuel, and oils, whose associated organic molecules have been described above. Other sources of organic pollution representing lower volumes come from the coolant, the windscreen washer, and detergents.

2.4. Maintenance of Coolant Circuit

A coolant is used to cool the engine and prevent overheating by maintaining a temperature between 75 °C and 95 °C. The coolant is composed of ethylene glycol and propylene glycol (30% to 50%). Water and additives, such as corrosion inhibitors for hose protection, are also used in its formulation [22]. The high proportion of ethylene glycol makes it possible to maintain a constant temperature in all seasons, since the liquid does not boil at 100 °C and only freezes below −20 °C. The used coolant is collected in the automotive center and then treated by an approved service provider. In automobile workshops, the poor handling of coolant can result in glycol ethers leaking onto the floor.

2.5. Windshield Washer Filling

Windscreen washer fluids are made with ethylene glycol, one or more alcohols, and water. For cost reasons, ethanol is usually used as the alcohol. However, some formulations contain methanol, which is toxic to humans, and its concentration in windscreen washer fluid has been limited by the European Union to 0.6% [23]. Nonylphenols can also be used in the cleaner formulation at concentrations between 2.2 to 5.2 $\mu g\ L^{-1}$ [1]. In car centers, leveling of the windscreen washer fluid is carried out during the maintenance of the vehicle. This liquid does not require purging of its circuit, so no liquid waste is produced during this service. The accidental deposit of coolant or windscreen washer fluid on the workshop floor, generally due to a circuit leak or improper handling, can consequently contribute to the introduction of ethylene glycol and propylene glycol into washing waters.

2.6. Detergents

Using detergents to clean specific parts of the vehicle, such as the rim, windshield, and brakes, is an integral part of the services carried out in an automobile workshop since it allows the vehicle to be returned to the customer in good visual condition after a repair or maintenance activity. Detergents are also regularly used for cleaning automobile workshop floors, the organic compounds of which are directly mixed with the washing water. There is high variability in detergent formulation. However, the active molecule most used in these cleaning products belongs to the group of alkylbenzene sulfonates [24,25].

3. Organic Compounds with a High Risk of Leakage to Be Monitored as a Priority in Washing Water

Services carried out in the workshop can lead to the release of well-known organic pollutants onto the ground. In this second part of our paper, we briefly present some of their main physicochemical characteristics (Table 1), which affect their behavior in washing water and after their discharge into the environment.

Table 1. List of priority organic compounds to be monitored in wash water and their physicochemical properties.

Pollutant	Sources	Some Physicochemical Properties
N-alkanes	Changing and shear stresses with the floor Braking system servicing Fuel leak from an injector Oil leak during engine and gearbox maintenance Floor cleaning with detergents	Depend on the length of the carbon chain n-octane: Log Kow * 5.34, WS ** 0.632 mg L^{-1} n-heptadecane: Log Kow 10.92, WS 0.0017 mg L^{-1}
Polycyclic aromatic hydrocarbons (PAHs)	Changing and shear stresses with floor Braking system servicing Used oil leak during oil change Improper storage of used oil	Depend on number of benzene rings benzo[a]pyrene: Log Kow 6.06, WS 0.0038 mg L^{-1}
Glycol ethers	Brake fluid replacement Maintenance of coolant circuit Windshield washer filling	Soluble or miscible (water) Log Kow −1.46 to 1.9
Alkylbenzenes	Vehicle structures and floor cleaning with detergents	Hydrophobic, Log Kow 7 to 10

* Kow: octanol water partition coefficient, ** WS: water solubility.

3.1. N-alkanes

N-alkanes are hydrocarbons made up of only carbon and hydrogen atoms separated into two categories: linear or branched aliphatic hydrocarbons with C_nH_{2n+2} as the molecular formula and cycloalkanes (C_nH_{2n}) with one or more carbon ring [16]. Saturated linear aliphatic hydrocarbons, also called paraffins, are frequently identified in tires, brake systems, fuels, and motor oils. Paraffins are divided into four groups: gaseous alkanes (<C8), low-molecular-weight aliphatic hydrocarbons (C8–C16), medium-molecular-weight aliphatic hydrocarbons (C17–C28), and heavy-molecular-weight aliphatic hydrocarbons (>C28) [26]. Their physicochemical properties depend on the length of their carbon chain. The higher the number of carbon atoms, the more these compounds are hydrophobic, insoluble in water, apolar, and weakly volatile. In the environment, paraffins mainly accumulate in soils or sediments due to their high hydrophobicity, their ability to persist for long periods, their weak volatilization, and leaching phenomena [27]. In sediments, their concentrations can vary, and their biodegradation is governed by dioxygen gradients and takes longer in anaerobic conditions [28,29].

3.2. Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are composed of only carbon and hydrogen atoms, structured by two or more benzene nuclei and assembled in linear, angular, or grouped forms [30]. They are classified into two categories: low-molecular-weight PAHs with up to two or three aromatic rings and high-molecular-weight PAHs with more than three rings. PAHs are hydrophobic molecules with low saturation vapor pressures, whose persistence and toxicity in the environment increase with the number of cycles. The International Agency for Research on Cancer has classified 15 PAHs. Among them, benzo(a)pyrene is considered a Group 1 carcinogen, and cyclopenta(c,d)pyrene, dibenzo(a,h)anthracene, and dibenzo(a,l)pyrene are identified as probable carcinogens (Group 2A). Eleven other compounds are classified as possible carcinogens (Group 2B), and the rest of these substances are unclassifiable (Group 3) [31]. With regard to the toxicity of this family of compounds in aquatic environments, due to their low solubility, chemical stability, and tendency to accumulate in the sediments [32] (due to a high octanol water partition coefficient, i.e., fluoranthene (Log Kow 5.16), benzo[a]pyrene (Log Kow 6.06), and indo(1,2,3-cd)pyrene (Log Kow 6.58)), the WFD set the following objectives to reduce or eliminate emissions of several PAHs by 2027 when action is possible [33]: fluoranthene emissions should be reduced by 10%, those of naphthalene by 30%, and those of benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, and indo(1,2,3-cd)pyrene by 100%.

In automobile workshops, n-alkanes and PAHs require special vigilance with regard to washing water contamination due to their abundance in a wide range of inputs like tires, braking systems, and mineral oils. This diversity of sources increases the probability of these organic compounds flowing onto the ground if preventive measures are not put in place. In addition, few substitute products for those containing paraffins and PAHs can be considered. In car workshops, this family of pollutants is strictly regulated. This is why water pre-treatment systems, called hydrocarbon separators, are generally installed to separate hydrocarbons from industrial wastewater.

3.3. Glycol Ethers

Glycol ethers are amphiphilic solvents divided into two categories and comprising more than 80 chemical substances. E-series glycol ethers, derived from ethylene glycol, have the generic formula R-(O-CH_2-CH_2)$_n$-O-R′ [34]. They are produced from the reaction between an ethylene oxide and an aliphatic monoalcohol in the presence of a catalyst [35]. The most commonly used alcohols for the formation of glycol ethers are methanol, ethanol, n-propanol, isopropanol, n-butanol, and n-hexanol. The P-series glycol ethers are derived from propylene glycol, whose generic molecular formula is R-(O-CH_2-CH(CH_3))$_n$-O-R′. They are synthesized from propylene oxide and water [34]. All the E- and P-series glycol ethers are soluble in water, and some are miscible, with Log Kow values ranging between −1.46 and 1.79 for the E-series and −0.4 and 1.9 for the P-series [36,37].

Glycol ethers are colorless and moderately volatile liquids with an amphiphilic character. They are used in the manufacturing of many products, such as functional fluids (brake fluids, cutting oil), windscreen washer fluids, industrial cleaning agents, and glues [38]. In 2010, the world market represented an annual production of 13 million tons of glycol ethers. Due to their physicochemical properties, these compounds are soluble in water, with weak accumulation in soils and sediments [36,37]. Glycol ethers are rapidly degraded by abiotic or biological processes in aquatic environments; therefore, their transfer to the food chain is limited [39]. Several regulations govern the production and use of glycol ethers. Eleven glycol ethers are considered reprotoxic according to classification, labeling, and packaging regulations [40]. These eleven substances are prohibited in cosmetic formulations. In addition, the Restriction, Evaluation, Authorization, and Restriction of Chemicals (REACH) regulations require an authorization procedure for the use of bis (2-methoxyethyl) oxide due to its reprotoxic properties. Finally, the French Labor Code requires companies to assess risks, control exposure, and implement prevention and training measures to protect teams from carcinogenic, mutagenic, and toxic substances for reproduction, including glycol ethers like 1,2-diethoxyethane, 2-methoxyethanol, 2-methoxyethyl acetate, 2-ethoxymethanol, 2-ethoxyethyl acetate, bis (2-methoxyethyl) oxide, 1,2-bis(2-methoxyeehoxy) ethane, 2-methoxypropyl acetate, and 2-(2-methoxyethoxy) ethanol [39].

In automotive workshops, the main risk of glycol ethers spilling onto the floor comes from incorrect use of the products during brake fluid replacement, cooling circuit maintenance, or windshield washer refilling. Once mixed with the workshop washing water, the glycol ethers are not eliminated from the water by the possible installation of a hydrocarbon separator due to their amphiphilic nature.

3.4. Alkylbenzenes

Since the 1960s, alkylbenzenes have been used as precursors for the manufacture of alkylbenzene sulfonates, one of the most widely used anionic surfactants in detergent production since the abandonment of natural soaps (due to their inferior detergent properties and higher production cost) [41]. Alkylbenzenes have a benzene ring linked to an alkyl chain ranging from 10 to 24 carbon atoms to constitute a subfamily of 26 compounds. They are synthesized by the dehydrogenation of paraffin, resulting in the subsequent alkylation of the benzene ring due to the loss of hydrogen atoms [41].

These hydrophobic compounds, whose Log Kow value varies between 7 and 10, are impurities resulting from the incomplete sulfonation of alkylbenzene sulfonates, listed at a rate of 13% in the final composition of the detergent [41]. The massive use of detergents in a wide variety of industries makes linear alkylbenzenes ubiquitous compounds in aquatic environments, especially surface waters and estuaries, where they tend to adsorb into suspended matter and accumulate in sediments. Their persistence in the environment and their proven bioaccumulation in aquatic fauna [42,43] make them indicators of the presence of other organic substances in the aquatic environment [44]. The toxicity of alkylbenzenes is little studied, unlike that of alkylbenzene sulfonates. Alkylbenzenes are not toxic to a wide variety of aquatic species, except for *Daphnia magna* [42,45]. The chronic ecotoxicity of alkylbenzene sulfonates to aquatic organisms has been extensively studied due to the large quantities discharged into the environment. Depending on the species, the concentrations at which chronic effects are observed vary between 250 and 10,000 $\mu g\ L^{-1}$ [46]. Additionally, these substances contribute to the permeation of other toxic compounds into aquatic animals [24]. Alkylbenzene sulfonates are mostly treated in wastewater treatment plants in an activated sludge process [47], and some of them are degraded by indigenous microorganisms when they reach the natural receiving environment. The undegraded quantity could inhibit the growth, reproduction, and physiological functions of aquatic organisms by acting on their membrane permeability, their enzymatic activity, and their tissue structure [48]. The toxicity of alkylbenzene sulfonates decreases with the water hardness and the adsorption and precipitation mechanisms occurring in surface waters [49].

In automobile workshops, due to the daily use of detergents to clean certain vehicle structures and the workshop floor, monitoring this family of compounds in the washing water discharged is necessary. Moreover, detergents could also be easily substituted with cleaning products with more environmentally friendly formulations without alkylbenzenes. This preventive method could reduce the risk of dispersing alkylbenzene sulfonates in wastewater.

3.5. Monitoring the Organic Pollution of Car Workshop Floor Wash Water

Automotive workshops discharge large volumes of floor washing water daily, ranging between 15 L and 50 L. French legislation requires automotive professionals to pre-treat these wash waters to make them safe for discharge by installing a hydrocarbon separator, also called an oil–water separator (OWS) [50]. This equipment makes it possible to reduce the load of organic pollutants in water by removing hydrocarbons by mechanical action based on gravity and coalescence (Table 2) [51].

Table 2. Concentration of the organic pollutant load before and after treatment by hydrocarbon separator.

Organic Pollution Indicators	French Regulations	* Upstream of OWS	* Downstream of OWS
Chemical oxygen demand (COD)	1500 mg L^{-1}	1210–87,300 mg L^{-1}	866–1100 mg L^{-1}
Biochemical oxygen demand (BOD)	600 mg L^{-1}	740–10,200 mg L^{-1}	256–545 mg L^{-1}
Total hydrocarbons	5 mg L^{-1}	14–1100 mg L^{-1}	0.363–1.74 mg L^{-1}

* The given data are means of the organic pollutant load of floor wash water collected during sampling campaigns in French automobile workshops between 2020 and 2023.

Water analysis campaigns carried out on raw wash water upstream of OWS and after pre-treatment show that this system enables effluents to be discharged that comply with French regulations [50]. Data concerning other pollutants, such as PAHs, alkylbenzenes, and glycol ethers, are not communicated because these pollutants were not monitored in accordance with the above-mentioned standards. In France, the OWS-treated washing water enters the wastewater network and then reaches a wastewater treatment plant to be treated. In some other countries, it is likely that wash water is discharged directly into the environment without any prior treatment phase [52]. In addition to the installation of a washing water pre-treatment system [53], or when this implementation is impossible, we offer a simple environmental risk prevention management tool based on a criticality matrix.

4. The Criticality Matrix: An Environmental Management Tool

4.1. Goals

To anticipate the flow risks associated with the main products used in car workshops, we propose the design of a criticality matrix, an already existing tool in risk prevention management, specifically applied in this study for pollution management in workshops. The criticality matrix is widely used by the health, safety, and environment (HSE) departments of companies as part of risk analyses, where it constitutes the initial and essential step of any prevention approach. This tool is simple to set up and allows for the reduction at the source in pollution coming from products at high risk of spillage that cause harm to the environment and lower the safety of car workshop teams (risk of slipping and falling). This environmental risk management approach makes it possible to identify products used in workshops that have a high risk of leakage and would require the installation of prevention equipment. This criticality matrix could also be used as a support tool when making decisions about the integration of new products.

4.2. Presentation of the Criticality Matrix

The identification of the products most used in Norauto's automobile workshops was carried out based on internal company data relating to their frequency of use and the repair and maintenance services most frequently carried out. Nine product categories were identified and coded as follows: engine oil (R1), cooling liquid (R2), transmission oil (R3), penetrating oil (R4), rim cleaner (R5), leak detector (R6), brake fluid (R7), brake cleaner (R8), and floor detergent (R9). The products coded R1, R3, and R4, representing 33% of the commonly used products, are oils employed for engine protection, gearbox operation, and mechanical piece lubrication, respectively. These products are potential sources of BTEX, n-alkanes (mid and long chains), isoalkanes, cycloalkanes, and aromatic compounds including PAHs. The second category of products extensively used in the workshops (33%) were detergents, coded R9, that could also ultimately be found in the washing water. Whatever the daily activity of a workshop and the services performed, detergents were commonly used every day for cleaning at a concentration of 2.5%. The remaining 33% was divided between other products, coded R2, R5, R6, R7, and R8. Some products like coolant liquid (R2) and brake fluid (R7) are potential sources of ethylene and propylene glycol.

The forecast model for the flow of products on the ground was designed based on a risk prevention tool, called the criticality matrix, the purpose of which is to assess the criticality of a risk. To make this calculation, two factors were considered. The first was the probability of product flow during its use, which was defined according to three criteria: the frequency of the workshop ticket rate (WTR), the target of the product, and the product phase (aerosol, paste, or liquid). These three criteria were chosen in consultation with the HSE manager and on the basis of feedback from car workshop teams. The first criterion, WTR frequency, corresponds to the rate of passage of a vehicle in a workshop for a specific service and is therefore linked to the frequency of use of a product. The higher the WTR, the higher the probability of a product spill. The second criterion defines the application target of the products used during the service rendered, i.e., the car part on which the product was applied. Three cases could be distinguished: the product was used inside the vehicle, but its flow was no longer possible because it was applied in a closed part of the vehicle (for example, oil, brake fluid, coolant. . .), representing a low impact of 1; the product was used inside the vehicle with a possible risk of flow (such as a degreasing agent applied to the surface of mechanical parts like nuts), representing a medium impact of 2; or the product was applied on the external surface of the vehicle, for example, leak detectors applied to the surface of the tires, corresponding to high impact of 3. The third criterion used for evaluating the probability factor was the phase of the product used during vehicle maintenance or repair, i.e., aerosol, paste, or liquid. For each of these criteria, three values could be assigned, i.e., 1, 2, or 3, permitting the calculation of the probability factor (Table 3).

Table 3. Rating of the frequency, target, and phase of the products to evaluate the probability factor criteria.

Impacts	Frequency	Target	Phase
Low = 1	WTR * < 10%	Product used in the vehicle mechanics; its flow no longer possible	Aerosol
Medium = 2	WTR: 10–50%	Product used in the vehicle mechanics; its flow still possible	Paste
High = 3	WTR > 50%	Product used on the vehicle external surface	Liquid

* WTR: workshop ticket rate.

Although the possibility of human influence is also a criterion to be considered in defining of the flow probability, its evaluation is quite difficult due to the diversity of the practices put in place. In addition, the attention and rigor given to a task to be carried out are specific to each mechanic. For these reasons, this criterion was not taken into account in this study.

The probability factor was calculated by averaging the impact levels of each criterion to obtain a factor between 1 and 3. Similarly, a second factor, called the prevention factor, was calculated by considering whether means of prevention implemented to avoid or limit the product flow on the ground exist. If there was a means of prevention, the lowest score would be 1 (for example, brake fluid change using an automatic bleeder). In the opposite situation, the highest score would be 3 (Table 4).

The leak risk score was then calculated by multiplying the mean leak probability factor by the prevention factor. These two factors were used to develop a criticality matrix, with a score between 1 and 9 (Table 5).

Table 4. Rating on the prevention factor.

Impacts	Prevention Factor
Low = 1	A prevention solution is systematically used by mechanics
Medium = 2	A prevention solution is partially used by mechanics
High = 3	No preventative solution exists

Table 5. Criticality matrix model.

Criticality Matrix				
Probability	3	3	6	9
	2	2	4	6
	1	1	2	3
		1	2 Prevention	3

The run-out risk score for each of the most used products in Norauto's automobile workshops, detailed previously (R1 to R9), was determined by multiplying the product run-out probability factor by the impact of the prevention factor (Table 6).

Table 6. Product categories used in automobile workshops and criteria used for calculating leak risk score.

Categories	Code	Frequency	Target	Phase	Probability Factor	Prevention Factor	Risk Score
Engine oil	R1	2	1	3	2	2	4
Cooling liquid	R2	2	1	3	2	3	6
Transmission oil	R3	1	1	3	1.7	3	5.1
Penetrating oil	R4	2	3	1	2	3	6
Rim cleaner	R5	3	3	1	2.3	3	6.9
Leak detector	R6	3	3	2	2.7	3	8.1
Brake fluid	R7	1	1	3	1.7	1	1.7
Brake cleaner	R8	1	1	3	1.7	3	5.1
Floor detergent	R9	3	3	3	3	3	9

Table 6 can be visualized by Figure 1.

This matrix shows that the product with the lowest risk of spillage was brake fluid (R7) due to the strong impact of its liquid phase. Its prevention factor was minimal since a preventive solution was already used by the teams, based on feedback about workshop practices. Detergent (R9) had the highest risk of spillage because it was used to clean the workshop floors, making this a logical finding. The products (apart from detergent) with the greatest risk of spillage were the rim cleaner (R5) and the leak detector (R6) used for tire maintenance, as defined by a high frequency of use, application to the exterior surface of the vehicle, and a non-existent means of prevention. Six of the nine product categories studied had a probability factor equal to or less than 2, of which five had a run-out risk score equal to or greater than 4, which shows the importance of implementing risk management prevention tools when possible (R2 and R3) and to ensure their systematic use when they are already in place (R1).

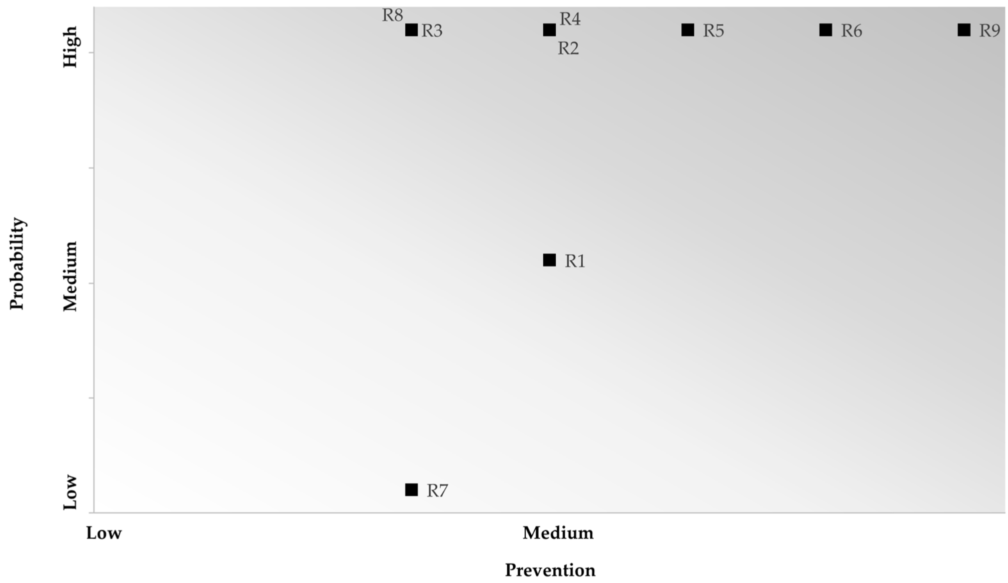

Figure 1. Criticality matrix applied to modeling of the risk of spillage on the workshop floor.

The designed criticality matrix is still a conceptual tool. Its effectiveness needs to be assessed in car workshops to determine its relevance and make improvements on the basis of expert feedback. Nevertheless, to the best of our knowledge, this approach is innovative, as it has not been widely used in the automotive workshop sector. However, the use of the criticality matrix has largely proven itself for the management of risks linked to the health and safety of employees, which in our opinion makes it a convincing tool that can be applied to other sectors of activity, such as the one proposed in the present study. It takes into account all the factors which make it possible to determine the risk of a product leaking onto the floor, namely, workshop tickets and the frequencies of associated services, the product phase and therefore its probability of dispersion, and the use of the product. At present, feedback from a large-scale deployment of this criticality matrix is needed to prove its relevance. Nevertheless, the implementation of a criticality matrix in automobile workshops as a tool for preventing environmental risks is only a first step and cannot be sufficient by itself. This tool must be supplemented with monitoring of the actions to be implemented (for example, introducing prevention equipment to limit the risk of product sales), which requires time and financial resources.

5. Conclusions

This literature review first describes the potential sources of organic pollution in a car workshop during vehicle maintenance and repair. Services with a high risk of products spilling onto the floor include changing tires (due to the shear stresses between the tires and the ground), braking system servicing, fuel leaking from an injector, oil leaking during engine and gearbox maintenance, used oil leaking during an oil change, improper storage of used oil, maintenance of the coolant circuit, windshield washer filling, and the use of detergents to clean the workshop floor and certain parts of the vehicle.

N-alkanes, PAHs, glycol ethers, and alkylbenzenes are the compounds to be monitored as a matter of priority due to their presence in the most frequently used products in automotive workshops and their high risk of flowing onto the ground. When hydrocarbon separators are present and in good working order in the automotive workshop, n-alkanes, PAHs, and alkylbenzenes are pre-treated on site. However, it seems necessary to reduce, where possible, emissions of organic pollution at their source, upstream of this treatment system.

In an approach to managing the environmental impacts of automobile workshops on water, a flow criticality matrix, which is a widely used risk prevention management tool, was applied to help professionals limit the risk of products spilling onto the floor.

At present, the designed criticality matrix is still a conceptual tool, and its effectiveness needs to be assessed in car workshops. Moreover, this study should be followed in the near future by a quantitative and qualitative assessment of the effluents generated in automotive workshops in order to identify pollution flows and evaluate the environmental risk generated by this sector and, consequently, its contribution to municipal wastewater treatment plants. Precise knowledge of the inputs and pollution generated by this sector, as with other light industrial sectors, will raise awareness of the importance of protecting water as a precious resource, which is one of the pillars of sustainable development.

In fact, the management of automotive workshop effluents will be a major challenge for professionals in the sector in the years to come. In 2027, the member states of the Europe will have to achieve the environmental objectives established by the WFD, which will probably undergo a strengthening of controls on the quality of effluents and the polluter pays policy. This issue is reinforced by the regular episodes of drought observed in France, as well as at the European and world level. These are estimated to cause reductions in the available water resources, resulting in a reduction in the recharge of groundwater bodies of between 6% and 46% and a decrease in average river flows of 25% to 40% in France by 2070 [54]. Actions that can be implemented upstream of water discharge include raising the awareness of all workshop stakeholders on water issues, replacing, when possible, the products used with formulations that are better for the environment, and the integration of prevention measures to limit the risk of products spilling onto the floor. To accompany these recommendations, curative methods of treatment of car workshop wash waters are recommended, such as improving the existing methods, developing new processes, or making these treatments mandatory. For example, membrane filtration, electrodialysis, adsorption, advanced oxidation, electrochemical processes, and biological systems seem to be effective technologies to treat industrial effluents of various origins [55–60].

More generally, the current water crisis will, in future years, force public and private actors to rethink the management of this resource by implementing sustainable water saving and treatment solutions.

Author Contributions: R.B., E.V. and C.R. contributed to the conceptualization and ideas in this manuscript. R.B., E.V. and C.R. commented the previous versions of the manuscript. F.K. and J.D. contributed to the redaction of the criticality matrix. C.R. and A.-D.F. supervised this research. All authors contributed critically to subsequent drafts and gave final approval for publication. All authors have read and agreed to the published version of the manuscript.

Funding: R. Bouchiat's Ph.D. was supported by a Research and Technology French National association ANRT and Norauto fellowship. The authors thank NORAUTO for the UCEIV Laboratory ULCO financial support.

Data Availability Statement: The authors confirm that literature source data are included within the manuscript.

Conflicts of Interest: Authors Rémi Bouchiat, Fabien Kaczmarek, Julien Dorchy, and Anne-Danièle Fortunato were employed by the company Norauto. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Lamprea, K.; Bressy, A.; Mirande-Bret, C.; Caupos, E.; Gromaire, M.-C. Alkylphenol and Bisphenol A Contamination of Urban Runoff: An Evaluation of the Emission Potentials of Various Construction Materials and Automotive Supplies. *Environ. Sci. Pollut. Res.* **2018**, *25*, 21887–21900. [CrossRef] [PubMed]
2. Markiewicz, A.; Björklund, K.; Eriksson, E.; Kalmykova, Y.; Strömvall, A.-M.; Siopi, A. Emissions of Organic Pollutants from Traffic and Roads: Priority Pollutants Selection and Substance Flow Analysis. *Sci. Total Environ.* **2017**, *580*, 1162–1174. [CrossRef] [PubMed]
3. Tamis, J.E.; Koelmans, A.A.; Dröge, R.; Kaag, N.H.B.M.; Keur, M.C.; Tromp, P.C.; Jongbloed, R.H. Environmental Risks of Car Tire Microplastic Particles and Other Road Runoff Pollutants. *Microplast. Nanoplast.* **2021**, *1*, 10. [CrossRef]
4. Mallick, S.K.; Chakraborty, S. Bioremediation of Wastewater from Automobile Service Station in Anoxic-Aerobic Sequential Reactors and Microbial Analysis. *Chem. Eng. J.* **2019**, *361*, 982–989. [CrossRef]

5. Sarmadi, M.; Foroughi, M.; Najafi Saleh, H.; Sanaei, D.; Zarei, A.A.; Ghahrchi, M.; Bazrafshan, E. Efficient Technologies for Carwash Wastewater Treatment: A Systematic Review. *Environ. Sci. Pollut. Res.* **2020**, *27*, 34823–34839. [CrossRef]
6. European Commission. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Policy in the Field of Water. In Official Journal No L 327 of 22 December 2000. pp. 1–73. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060 (accessed on 19 August 2022).
7. Kole, P.J.; Löhr, A.J.; Van Belleghem, F.; Ragas, A. Wear and Tear of Tyres: A Stealthy Source of Microplastics in the Environment. *Int. J. Environ. Res. Public. Health* **2017**, *14*, 1265. [CrossRef]
8. Wagner, S.; Hüffer, T.; Klöckner, P.; Wehrhahn, M.; Hofmann, T.; Reemtsma, T. Tire Wear Particles in the Aquatic Environment—A Review on Generation, Analysis, Occurrence, Fate and Effects. *Water Res.* **2018**, *139*, 83–100. [CrossRef]
9. Panko, J.M.; Chu, J.; Kreider, M.L.; Unice, K.M. Measurement of Airborne Concentrations of Tire and Road Wear Particles in Urban and Rural Areas of France, Japan, and the United States. *Atmos. Environ.* **2013**, *72*, 192–199. [CrossRef]
10. Rogge, W.F.; Hildemann, L.M.; Mazurek, M.A.; Cass, G.R.; Simoneit, B.R.T. Sources of Fine Organic Aerosol. 3. Road Dust, Tire Debris, and Organometallic Brake Lining Dust: Roads as Sources and Sinks. *Environ. Sci. Technol.* **1993**, *27*, 1892–1904. [CrossRef]
11. European Commission. Directive 2005/69/EC of the European Parliament and of the Council of 26 November 2005 Amending for the 27th Time Council Directive 76/769/EEC on the Approximation of the Laws, Regulations and Administrative Provisions of the Member States Relating to the Limitation of Marketing and Use of Certain Dangerous Substances and Preparations (Polycyclic Aromatic Hydrocarbons Contained in Extender Oils and Tyres). In Official Journal No L 323 of 9 December 2005. pp. 1–4. Available online: https://eur-lex.europa.eu/legal-content/FR/TXT/?uri=CELEX:32005L0069 (accessed on 9 August 2022).
12. Wahlström, J.; Olander, L.; Olofsson, U. Size, Shape, and Elemental Composition of Airborne Wear Particles from Disc Brake Materials. *Tribol. Lett.* **2010**, *38*, 15–24. [CrossRef]
13. Garg, B.D.; Cadle, S.H.; Mulawa, P.A.; Groblicki, P.J.; Laroo, C.; Parr, G.A. Brake Wear Particulate Matter Emissions. *Environ. Sci. Technol.* **2000**, *34*, 4463–4469. [CrossRef]
14. Alves, C.; Evtyugina, M.; Vicente, A.; Conca, E.; Amato, F. Organic Profiles of Brake Wear Particles. *Atmos. Res.* **2021**, *255*, 105557. [CrossRef]
15. Caban, J.; Vrábel, J.; Šarkan, B.; Kuranc, A.; Słowik, T. Operational Tests of Brake Fluid in Passenger Cars. *Period. Polytech. Transp. Eng.* **2020**, *49*, 126–131. [CrossRef]
16. Colombano, S.; Saada, A.; Victoire, E.; Guerin, V.; Zornig, C.; Amalric, L.; Blessing, M.; Widory, D.; Hube, D.; Blanc, C.; et al. Nature of petroleum products and origin of aging: Attempt to identify the source by taking into account the impacts and analyzing the approximate age of the spills. *Final BRGM Rep.* **2014**, 1–166. Available online: https://ssp-infoterre.brgm.fr/fr/rapport/nature-produits-petroliers (accessed on 19 July 2022).
17. Solano-Serena, F.; Marchal, R.; Vandecasteele, J.P. Biodégradabilité de l'essence dans l'environnement: De l'évaluation globale au cas des hydrocarbures récalcitrants. *Oil Gas Sci. Technol.* **2001**, *56*, 479–498. [CrossRef]
18. Marchal, R.; Penet, S.; Solano-Serena, F.; Vandecasteele, J.P. Gasoline and Diesel Oil Biodegradation. *Oil Gas Sci. Technol.* **2003**, *58*, 441–448. [CrossRef]
19. Ramadass, K.; Megharaj, M.; Venkateswarlu, K.; Naidu, R. Ecological Implications of Motor Oil Pollution: Earthworm Survival and Soil Health. *Soil Biol. Biochem.* **2015**, *85*, 72–81. [CrossRef]
20. Aluyor, E.O.; Ori-jesu, M. Biodegradation of Mineral Oils—A Review. *Afr. J. Biotechnol.* **2009**, *8*, 6.
21. Vazquez-Duhalt, R. Environmental Impact of Used Motor Oil. *Sci. Total Environ.* **1989**, *79*, 1–23. [CrossRef]
22. Starostin, M.; Tamir, S. New Engine Coolant for Corrosion Protection of Magnesium Alloys. *Mater. Corros.* **2006**, *5*, 345–349. [CrossRef]
23. Directorate-General for Internal Marlet, Industry, Entrepreneuship and SMEs. New Restriction on Methanol in Car Windscreen Washing Fluids. European Commission Press Release. Available online: https://single-market-economy.ec.europa.eu/news/new-restriction-methanol-car-windscreen-washing-fluids-2018-04-18_en (accessed on 18 August 2022).
24. Sablayrolles, C.; Breton, A.; Vialle, C.; Vignoles, C.; Montréjaud-Vignoles, M. Priority Organic Pollutants in the Urban Water Cycle (Toulouse, France). *Water Sci. Technol.* **2011**, *64*, 541–556. [CrossRef] [PubMed]
25. Mousavi, S.A.; Khodadoost, F. Effects of Detergents on Natural Ecosystems and Wastewater Treatment Processes: A Review. *Environ. Sci. Pollut. Res.* **2019**, *26*, 26439–26448. [CrossRef]
26. Abbasian, F.; Lockington, R.; Mallavarapu, M.; Naidu, R. A Comprehensive Review of Aliphatic Hydrocarbon Biodegradation by Bacteria. *Appl. Biochem. Biotechnol.* **2015**, *176*, 670–699. [CrossRef] [PubMed]
27. Stroud, J.L.; Paton, G.I.; Semple, K.T. Microbe-Aliphatic Hydrocarbon Interactions in Soil: Implications for Biodegradation and Bioremediation. *J. Appl. Microbiol.* **2007**, *102*, 1239–1253. [CrossRef] [PubMed]
28. Kanzari, F.; Syakti, A.D.; Asia, L.; Malleret, L.; Piram, A.; Mille, G.; Doumenq, P. Distributions and Sources of Persistent Organic Pollutants (Aliphatic Hydrocarbons, PAHs, PCBs and Pesticides) in Surface Sediments of an Industrialized Urban River (Huveaune), France. *Sci. Total Environ.* **2014**, *478*, 141–151. [CrossRef]
29. Wang, M.; Wang, C.; Hu, X.; Zhang, H.; He, S.; Lv, S. Distributions and Sources of Petroleum, Aliphatic Hydrocarbons and Polycyclic Aromatic Hydrocarbons (PAHs) in Surface Sediments from Bohai Bay and Its Adjacent River, China. *Mar. Pollut. Bull.* **2015**, *90*, 88–94. [CrossRef]
30. Abdel-Shafy, H.I.; Mansour, M.S.M. A Review on Polycyclic Aromatic Hydrocarbons: Source, Environmental Impact, Effect on Human Health and Remediation. *Egypt. J. Pet.* **2016**, *25*, 107–123. [CrossRef]

31. Environmental Cancer Prevention Department Leon Berard Cancer Center. Polycyclic Aromatic Hydrocarbons. Available online: https://www.cancer-environnement.fr/fiches/expositions-environnementales/hydrocarbures-aromatiques-polycycliques-hap/ (accessed on 29 August 2022).
32. Brignon, J.; Soleille, S. Données technico-économiques sur les substances chimiques en France—Hydrocarbures Aromatiques Polycycliques. *INERIS* **2006**, 1–50. Available online: https://substances.ineris.fr/fr/page/14 (accessed on 26 August 2022).
33. Ministry of Ecological Transition and Territorial Cohesion. Technical note of 20 September 2020 relating to the national objectives for reducing emissions, discharges and losses of hazardous substances in surface waters and their implementation in the SDAGEs 2022–2027. *Fr. Republic.* **2020**, 1–20. Available online: https://www.bulletin-officiel.developpement-durable.gouv.fr/notice?id=Bulletinofficiel-0031593&reqId=4ef35dfc-a41e-40b1-9c27-8e626220c821&pos=5 (accessed on 16 February 2022).
34. De Ketttenis, P. The Historic and Current Use of Glycol Ethers: A Picture of Change. *Toxicol. Lett.* **2005**, *156*, 5–11. [CrossRef]
35. Kelsey, J.R. Ethylene Oxide Derived Glycol Ethers: A Review of the Alkyl Glycol Ethers Potential to Cause Endocrine Disruption. *Regul. Toxicol. Pharmacol.* **2022**, *129*, 105113. [CrossRef] [PubMed]
36. Staples, C.A.; Boatman, R.J.; Cano, M.L. Ethylene Glycol Ethers: An Environmental Risk Assessment. *Chemosphere* **1998**, *36*, 1585–1613. [CrossRef] [PubMed]
37. Staples, C.A.; Davis, J.W. An Examination of the Physical Properties, Fate, Ecotoxicity and Potential Environmental Risks for a Series of Propylene Glycol Ethers. *Chemosphere* **2002**, *49*, 61–73. [CrossRef] [PubMed]
38. Multigner, L.; Catala, M.; Cordier, S.; Delaforge, M.; Fenaux, P.; Garnier, R.; Rico-Lattes, I.; Vasseur, P. The INSERM Expert Review on Glycol Ethers: Findings and Recommendations. *Toxicol. Lett.* **2005**, *156*, 29–37. [CrossRef] [PubMed]
39. Lenoble, C.; Gouzy, A.; Brignon, J. Données technico-économiques sur les substances chimiques en France—Ethers de glycol. *INERIS* **2015**, 1–43. Available online: https://substances.ineris.fr/fr/page/14 (accessed on 26 August 2022).
40. European Commission. Regulation n°1272/2008 of the European Parliament and of the Council of 16 December 2008 Relating to the Classification, Labeling and Packaging of Substances and Mixtures, Amending and Repealing Directives 67/548/EEC and 1999/45/EC and Amending Regulation (EC) No 1907/2006. In Official Journal No L 353 of 31 December 2008. pp. 1–1355. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32008R1272 (accessed on 3 November 2022).
41. Kocal, J.A.; Vora, B.V.; Imai, T. Production of Linear Alkylbenzenes. *Appl. Catal. Gen.* **2001**, *221*, 295–301. [CrossRef]
42. Fernández, C.; Alonso, C.; García, P.; Tarazona, J.V.; Carbonell, G. Toxicity of Linear Alkyl Benzenes (LABs) to the Aquatic Crustacean Daphnia Magna through Waterborne and Food Chain Exposures. *Bull. Environ. Contam. Toxicol.* **2002**, *68*, 637–643. [CrossRef] [PubMed]
43. Saldaña-Serrano, M.; Bastolla, C.L.V.; Mattos, J.J.; Lima, D.; Freire, T.B.; Nogueira, D.J.; De-la-Torre, G.E.; Righetti, B.P.H.; Zacchi, F.L.; Gomes, C.H.A.M.; et al. Microplastics and Linear Alkylbenzene Levels in Oysters Crassostrea Gigas Driven by Sewage Contamination at an Important Aquaculture Area of Brazil. *Chemosphere* **2022**, *307*, 136039. [CrossRef]
44. Ni, H.-G.; Lu, F.-H.; Wang, J.-Z.; Guan, Y.-F.; Luo, X.-L.; Zeng, E.Y. Linear Alkylbenzenes in Riverine Runoff of the Pearl River Delta (China) and Their Application as Anthropogenic Molecular Markers in Coastal Environments. *Environ. Pollut.* **2008**, *154*, 348–355. [CrossRef]
45. Gledhill, W.E.; Saeger, V.W.; Trehy, M.L. An Aquatic Environmental Safety Assessment of Linear Alkylbenzene. *Environ. Toxicol. Chem.* **1991**, *10*, 169–178. [CrossRef]
46. Belanger, S.E.; Brill, J.L.; Rawlings, J.M.; Price, B.B. Development of Acute Toxicity Quantitative Structure Activity Relationships (QSAR) and Their Use in Linear Alkylbenzene Sulfonate Species Sensitivity Distributions. *Chemosphere* **2016**, *155*, 18–27. [CrossRef] [PubMed]
47. Mungray, A.K.; Kumar, P. Fate of Linear Alkylbenzene Sulfonates in the Environment: A Review. *Int. Biodeterior. Biodegrad.* **2009**, *63*, 981–987. [CrossRef]
48. Zhou, J.; Wu, Z.; Yu, D.; Pang, Y.; Cai, H.; Liu, Y. Toxicity of Linear Alkylbenzene Sulfonate to Aquatic Plant *Potamogeton perfoliatus* L. *Environ. Sci. Pollut. Res.* **2018**, *25*, 32303–32311. [CrossRef] [PubMed]
49. Verge, C.; Moreno, A. Infuence of Water Hardness on the Bioavailability and Toxicity of Linear Alkylbenzene Sulphonate (LAS). *Chemosphere* **2001**, *44*, 1749–1757. [CrossRef] [PubMed]
50. Greater Avignon Urban Area Community. Order authorising the discharge of non-domestic wastewater from the Avignon Sud Norauto garage into the Avignon municipal collection system. 24 July 2014; 1–3, (pers. com.).
51. *EN 858-1:2001*; Separator Systems for Light Liquids (Oil and Petrol)—Part 1: Principles of Product Design, Performance and Testing, Marking and Quality Control. European Standard AFNOR: Saint-Denis, France, 2001; pp. 1–72.
52. Yu, L.; Han, M.; He, F. A review of treating oily wastewater. *Arab. J. Chem.* **2017**, *10*, S1913–S1922. [CrossRef]
53. Mazumder, D.; Mukherjee, S. Treatment of automobile service station wastewater by coagulation and activated sludge process. *Int. J. Environ. Sci. Devel.* **2011**, *2*, 64–69. [CrossRef]
54. Hauts-de-France Regional Economic, Social and Environmental Council (CESER). Towards a Major Water Policy in Hauts-de-France. In Report Following the CESER Opinion Adopted on 26 April 2022. pp. 1–176. Available online: https://ceser.hautsdefrance.fr/rapports/article/vers-une-grande-politique-de-l-eau-en-hauts-de-france-833 (accessed on 23 November 2022).
55. Campos, J.C.; Borges, R.M.H.; Oliveira Filho, A.M.; Nobrega, R.; Sant'anna, G.L., Jr. Oilfield wastewater treatment by combined microfiltration and biological processes. *Water Res.* **2002**, *36*, 95–104. [CrossRef]
56. Sirivedhin, T.; McCue, J.; Dallbauman, L. Reclaiming produced water for beneficial use: Salt removal by electrodialysis. *J. Membr. Sci.* **2004**, *243*, 335–343. [CrossRef]

57. Jamaly, S.; Giwa, A.; Hasan, S.W. Recent improvements in oily wastewater treatment: Progress, challenges, and future opportunities. *J. Environ. Sci.* **2015**, *37*, 15–30. [CrossRef]
58. Kuyukina, M.S.; Krivoruchko, A.V.; Ivshina, I.B. Advanced bioreactors treatments of hydrocarbon-containing wastewater. *Appl. Sci.* **2020**, *10*, 831. [CrossRef]
59. Carranza-Diaz, O.; Schultze-Nobre, L.; Moeder, M.; Nivala, J.; Kuschk, P.; Koeser, H. Removal of selected organic micropollutants in planted and unplanted pilot-scale horizontal flow constructed wetlands under conditions of high organic load. *Ecol. Eng.* **2014**, *71*, 234–245. [CrossRef]
60. Szarka, A.; Mihová, V.; Horváth, G.; Hrouzková, S. Development of an Advanced Inspection of the Degradation of Volatile Organic Compounds in Electrochemical Water Treatment of Paint-Industrial Water Effluents. *Appl. Sci.* **2023**, *13*, 443. [CrossRef]