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Review

Chemicals and Allied Products Waste Treatment

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Abstract: A review of the literature published from 2008 to 2010 on topics related to chemicals and allied products is presented. The review considered several sections such as waste management, physicochemical treatment, aerobic treatment, anaerobic treatment, air emissions, soils and groundwater, and reuse.

1. Introduction

Entering into the 21st century, science and engineering has made great strides in its technological advances for the treatment and handling of wastes related to chemicals and allied products. Having an origin that began with attempting to comply with federal regulations, the types of mechanisms that have been purposed to handle various wastes has changed due to increasing knowledge within the field. This can be attributed to the interdisciplinary collaboration between various science and engineering fields. While conventional waste handling techniques such as landfilling and conventional wastewater treatment are still in use, the emphasis has changed to reduce the amount of product following treatment and somehow generate a product from waste collected. This has led to the popularity of many techniques such as ozonation, ultraviolet irradiation, and other chemical treatment

methods. With the use of these new technologies, one is capable of treating wastes that have not been treated before due to the possible problems associated with using traditional methods. Having a plethora of opportunities to explore new technologies, it is therefore important to make a concerted effort to consider what has occurred within waste handling and treatment. The purpose of this text is to provide a study of waste handling methods that cover topics from 2008 to 2010 concerning waste management, physicochemical treatment, aerobic and anaerobic treatment, air emissions, soils and groundwater, and reuse for wastes related to chemicals and allied products.

2. Waste Management

Devi *et al.* discussed a novel method of treating zirconium radioactive waste by using ion-exchange resins for separation of cobalt and antimony from zirconium occurred, where the decontamination factor was greater than 10^3, achieved in an ion-exchange range with cobalt and antimony, reducing the waste volume [1]. Ko *et al.* found that conventional animal feeding operations (CAFOs) consider 424 microbial air samples and 12 CAFOs analyzed using indicator and pathogenic microorganisms, where 4.5% fecal coliform, 1.2% *E.coli*, 22.2% *Clostridium*, and 12.3% total coliphage. However, when alternative waste treatment technologies were applied, these technologies assisted in maintaining these microorganisms during on-farm treatment and management processes [2].

Cobo *et al.* compared 2-propanol and molecular H_2/MeOH as reducing agents for hydrodechlorination of dioxides with a 2% wt of Pd/gamme-Al_2O3 and concluded that complete dioxin degradation occurred when 2-propanol was a reducing agent and solvent, as compared with using H_2/MeOH which diminished the efficiency [3]. Schiffman *et al.* considered odor emissions from swine facilities modeling at a distance from 200 and 400 m downwind using an Eulerian-Lagrangian model. The results found that odor did not extend beyond a 400 m, as long as the air was not turbent within the day, while at night, cooling where stable boundary layer by long wave radiation, also swine housing was based on odor along with sources as compared to waste management types [4].

Muhle *et al.* compared municipal solid waste in Germany and the United Kingdom for overall emissions, where it was determined that Germany relied more on recycling and recovery as compared to the United Kingdom. The values reflected CO_2 emissions of 175 kg CO_2 equivalents/t in Germany, *versus* 34 kg CO_2 equivalents/t in the United Kingdom [5]. Roudil *et al.* considered a natural uranium oxide sample from Pet At Ran in Vendee region of France for the purpose of considering changes in UO_2 and (U, PuO_2) matrixes with nuclear waste management. Helium (He) diffusion coefficients showed that 5% maximum during 320 Ma was concerned; 33% residual that in matrix and vacancy and defects; 66% bubbles were found by HRTEM [6].

Davoli *et al.* conducted an integrated risk assessment study within 5 km from a landfill accepting non-hazardous waste, where factors such as emissions, maximum chronic population exposure. The overall effects look at carcinogenic compounds and diffusive emissions and noticed that cancer and non-cancer risks were lower than international agencies emissions such as World Health Organization and the United States Environmental Protection Agency [7].

Othman *et al.* considered compiling research on the presence of plastics and additional components that are within electronics that have the potential of being used within raw material and energy

recovery. It was discovered by using the Dulong formula that electronic waste has a calorific value of 30,872.42 kJ/kg, a value lower emissions for the Environment Quality Act of 1974 [8].

Zhang *et al.* concluded that considering the use of organiochlorine pesticide contamination and found that pesticides are present within those soils. In addition, the authors suggested that human population within the vicinity of the soils were under a threat to being exposed to those pollutions, as it requires treatment technologies to rid those pesticides from the soils [9]. Zhang *et al.* found that considering heavy metal contamination in municipal solid waste (MSW) in China, where Zn, Cr, Cu, and Pb is greater than 100 mg/kg, while Ni, Cd, and Hg followed. Because putrescible waste and indistinguishable particles (PU), plastics were the materials in the MSW, the authors considered a MSW management system using physicochemical fractionation [10].

Asrupt *et al.* concluded that receiving plastic waste in various forms such as clean, mixed/contaminated waste, and plastic waste as fuel at a material recover facility. The facility was able to save money on recycling the plastic, specifically in carbon dioxide emissions from electricity production; however, it was not responsive to global warming [11].

3. Physicochemical Treatment

Sorption. Homem *et al.* found that the optimum conditions for amoxicillin sorption is capable of completion when the initial concentration is 450 mu g/L, 50 mg/L adsorbent, temperature of 303 K, and dp 600 mu m. Pseudo second-order kinetics determined to be the best, as Langmuir was the best isotherm [12].

Bhatnagar *et al.* found that the maximum sorption capacity of nano-alumina for nitrate removal was 4.0 mg/g, 25 °C temperature, and a pH of 4.4. The nitrate sorption was expressed by means of a Langmuir isotherm model [13].

Wang *et al.* found that using a PS-EDTA resin for adsorbing Cu(II) and Pb(II) and found that a pH of 6, adsorption capacity removal efficiencies were 99.8% for Cu(II) and 99.6% for Pb(II, The kinetics were pseudo-second order model, where the column capacity for the two heavy metals were a bed height of 0.15 m, hydraulic loading rate of 2.5 m^3/hm^2, and feed concentrations of 50 and 100 mg/L [14].

Chen *et al.* stated that perfluorooctane sulfonate was sorbed by oil and oil-derived black carbon as there was a relationship with pH and also Ca^{+2}. In addition, the authors stated that environmental conditions and aqueous concentrations also were major influences when it came to black carbon within perfluoroctane sulfonate [15]. Mori *et al.* concluded that using crystal violet cationic dye onto polyether type polyurethane foam determined that the isotherms were Langmuir and Freundlich isotherms. It was also determined that at the optimum conditions would provide a removal efficiency of around 92% [16].

Li *et al.* concluded that removing 4-chlorophenol was capable by means of using beta-cyclodextrin polmer as it was noticed that high sorption capacity was registered when the initial concentration did not exceed 24.4 mg/g. It was also determined that the adsorption kinetics as a pseudo 2nd order equation [17].

Other Physical Chemical Methods. Zheng *et al.* found that ultrasound degradation combined with H_2O_2 of direct pink using NaCl and $CuSO_4$ when the pH was 3.0, power of 150 W, 78% degradation was achieved using 50 mu/L H_2O_2 and $CuSO_4$, and a treatment time of 120 min [18].

Katuri *et al.* concluded that using a laccase-membrane reactor for the decolorization of acid black 10 BX by means of white rot fungi *Pleurotus ostreatus 1804*, where it was determined that optimum treatment occurred at 30 ° Celsius, a reaction time of 120 min, pH of 6, and a concentration of 20 mg/L [19]. Hasal and Penizkova observed how Penicillin G is capable of being hydrolyzed by using a electro-membrane reactor, as it was contingent on the mean residence time, electric current density, and membrane enzyme activity. The authors determined that using electric current application would increased the conversion of Penicillin G by 200% [20].

Saravanane and Sundararaman discussed the effects of loading rate and hydraulic retention time on the removal of cephalsopsporin and its intermediates by using bioaugmentation. The authors stated that the purpose of this is to determine methods to remove the compounds prior to discharge as it is current against regulatory standards [21]. Mohan *et al.* found that using treatment with microbial fuel cells for chemical wastewater was contingent on power generation and organic substrate loading rate where optimum conditions were 716 mV, 2.84 mA, organic loading rate (OLR) of 1.105 kg COD/m^3 d and 731 mV, 2.97 mA, OLR of 1.404 kg COD/d. The maximum power was 0.73 kW/kg COD_R and 0.49 kg/COD_R, current density of 339.7 mA/m^2, and 335.43 mA/m^2 with a 50 ohm resistance [22].

Beler-Baykal and Allav compared real and simulated fertilizer wastewater samples that removal of ammonium, where surface capacities were at 14 ng Ammonium/g clinoptilolite. The authors found that using natural zeolite clinoptilolite as a treatment towards ammonium and nitrogen control is based on pH [23].

Oxidation, ozonation. Ruan *et al.* found that ozone with microelectrolysis was able to oxidize reactive red X-3B by removing 99% color, 85% COD, 59% TOC, and 74% AOX as long as the conditions were 1 g/L concentration, pH of 9, temperature of 60° Celsius, 400 g iron scrap with a diameter of 0.9 to 2.0 mm, and 10 g/h ozone flow rate [24]. Author Gulnaz concluded that the use of adsorption by *Chara vulgaris* was capable of removing various dyes within a pH range between 2 and 4, where adsorption was communicated by using pseudo-second order kinetics [25]. Turhan and Turgut concluded that the use of ozonation treatment for two hours was able to remove dyes within textile wastewater in half, specifically degradation that occurs within 10 min [26].

Merle *et al.* concluded that using adsorption and ozone compounds such as 2,4-dichlorophenol and nitrobenzene would be capable of decomposing compounds within the system, where activated carbon had a suitable adsorbent and decomposition of ozone [27]. Wang *et al.* concluded that by using a biofilter with ozone concluded that the chlorobenzene had the capability to increase by 50% when the ozone concentration increased to 120 mg/m^3 [28].

Garoma *et al.* found that oxidation of Bisphenol A (BPA) and its intermediation found that it was resistant to ozonation when BPA was registered at 51 M, corresponding of 2.1% catechol, 1.1% resorcinol, 0.9% acetone, and 0.3% formaldehyde of the initial concentration was present [29]. Gagnon *et al.* found that ozone could be a powerful disinfectant for pharmaceutical wastewater using UV radiation, and ozone and perfomic acid conducted in a Montreal Wastewater Treatment Plant. Removal of pharmaceutical waste triclosan was as high as 70%, relating to the presence of ozone (20 mg/L), while UV irritation only removed at 40% [30]. Di Iaconi *et al.* concluded that with a combination of a sequencing batch biofilm reactor (SBBR) to determine oxygen uptake rate, total protein content, extracellular polymeric substance, and hydrophobicity. The results determined that an

ozone dose of 120 mg/O$_3$-L, sludge production was reduced 25–30 times reducing 60% of the costs. However, biomass activity and structure were not affected by ozone [31].

Irridiation, catalysis, metal complexes. Xiao *et al.* found that total organic carbon (TOC) removal was 95% by catalytic ozonation of 2,4-dichlorophenol with permanganate [MnO$_4$] (0.5 mg/L), provided the pH is below 8.5. MnO$_4$ assistance in mineralization was affected by conditions, provided that the conditions were acidic, as MnO$_4$ was reduced to Mn^{+2} for homogenous catalysis [32]. Sanchez-Polo *et al.* considered gamma irritation as a way to decompose and mineralize nitroimidazoles, where it was noticed that by the presence of optimum H$_2$O$_2$, it is capable of accelerating the degradation of nitroimidazoles within acidic conditions. In addition, it was noticed that gamma irridiation was able to reduce toxicity within the system with increasing doses [33]. Authors Naddeo *et al.* concluded that by using sonolysis for wastewater remediation of pharmaceutical wastes is contingent on power densities, acidic conditions, and dissolved air presence. In addition, the authors reported a relationship between concentration of pharmaceuticals and also reaction rate, and also concluded that mineralization allows for complete biodegradation of by-products [34]. Wang *et al.* found that a photocatalytic reactor with a TiO$_2$ catalyst was capable of treating Acid Red 4, provided that the parameters considered are flow configuration, flow rate, dye concentration, height intensity, and catalyst loadings [35]. Wu and Li found recovery of phenol from 2,500 to 2 ppm using alkyl phenol from simulated wastewater in a horizontal membrane reactor, where ion-exchange capacity, water content, and membrane thickness. They used a quaternary ammonium membrane from polymerizing chloroethyl styrene and dimethylbenzene [36].

Extraction, electrolysis, electrochemical. Zhou *et al.* found total nitrogen (51.9%), NH$_4$-N (70%) and NO$_3$-N (50.94%) when treating pharmaceutical wastewater using an iron-carbon micro-electrolysis system, provided that iron/carbon granulation was 0.425 mm, pH of 3, iron-carbon ratio of 3, gas-water ratio of 5, and a hydraulic retention time of 1.5 h [37]. Prieto *et al.* compared solid-phase extraction and microextraction and concluded that both were capable of capturing pesticides. However, it depends on preference whether to use each type--solid-phase microextration is inexpensive, while solid-phase extraction is more precise [38].

Wang *et al.* concluded that by using internal micro-electrolysis coagulation, biological treatment, and activate carbon systems were capable of reducing COD up to 96% through the whole system, as it was determined that the majority of the processes within biological treatment were capable of removing the COD present in the wastewater. The authors concluded that the removal of COD was sufficient to meet Chinese tertiary discharge standards [39]. By using praseodymium, Han *et al.* used a SnO$_2$/Ti electrode for electrocatalysis was undergone through a model. From a model considering the optimum current density, electrolysis time, dope P-T, and (SnO$_2$/Ti: Al) ratio, COD wiping removed 94.6% COD (392 to 20 mg/L [40].

Novel process. Liu *et al.* determined that an integrated biological and electrochemical oxidation (BEO) with a boron-doped diamond electrode treating biorefactory pesticide wastewater with acetemiprid concentration of 1000 mg/L. The results concluded that BOD$_5$/TOC ratio was increased to 1.17 a 40% reduction in toxicity in 3 h, and a removal of acetamiprid and TOC [41]. Yang *et al.* introduced a combined microwave enhanced Fenton processes, making it possible to treat high concentrated pharmaceutical wastewater, with a 57% efficiency of COD and increase of the BOD$_5$/COD ratio from 0.165 to 0.470, exhibiting higher treatment efficiency. It was determined that

microwave power, radiation time, pH, and H_2O_2 and $Fe_2(SO_4)_3$ concentrations affected the treatment efficiency [42].

Hybrid proceses. Mozia *et al.* found that azo dye Acid Red 18 could remove 49–64% higher for the hybrid photocatalytic membrane reactor with photocatalysis and membrane distillation. The dye that considered a A-799-1 h catalyst developed by a loading of 0.5 g/dm^3. Preparation of catalyst was intensive—1 h calcinations with 700 °C from amorphous TiO_2 from the production line at a Chemical Factory Police in Poland [43].

4. Aerobic Treatment

Aerobic bio-treatment. Heger *et al.* considered four aerobic treatment systems to treat milkhouse wastewater on nine dairy farms, concluding that Biochemical Oxygen Demand (BOD) was removed from 539 mg/L to 173 mg/L, while Oils and Grease (O&G) reduced from 89 mg/L to 9 mg/L when the flow rate range was between 0.63 to 2.31 m^3/d using primary treatment in septic systems [44]. You and Teng compared an aerobic membrane bioreactor and aerobic membrane by means of *L. lactis* for the removal of Reactive Black 5 and concluded that the dye was successfully mineralized when using the combined system, while both treatment processes met the Taiwan EPA's effluent criteria. The water removed was capable of being used for other resources such as toilet flushing and landscaping [45].

Aerobic activated sludge reactors. Wang *et al.* experimented using aerobic granules in three sequencing batch reactors (SBR, One SBR was a control, while two had Cu(II) and Ni(II) with the heavy metal concentrations increasing to 15 mg/L. The results determined that Cu(II) was affected by biomass concentration, bioactivity, and biodiversity of the aerobic granules [46].

Using aerobic granular sequencing batch reactor (GSBR) with an inlet concentration of 100 to 2,000 mg phenol/L, cycle time between 14 and 24 h and filling cycling time between 1 and 4 h, Mourssavi *et al.* found that 99% phenol was removed from saline wastewater when phenol was 1,000 mg/L with a time of 17 h for cycle, while TDS was reported as 8% [47].

Authors Esteve *et al.* studied the use of an activated sludge aerobic treatment for the purpose of degrading thirteen pesticides, noticing that biological treatment can treat 97% of twelve of the thirteen pesticides. In addition, the authors noted that flocculation (sedimentation) must be added to maintain the biomass floc that had been destroyed by the pesticides [48].

Effects on treatment performance. Hussain *et al.* explored recent studies have concluded that pesticides have negative connotation for both plants and nitrogen fixing rhizobacteria, having an overall affect on the processes of biological nitrogen fixation, including addition processes such as nitrification, denitrification, ammonification, redox reactions, and methanogenesis [49].

Christian *et al.* used a high rate activated sludge reactor (HRAS) with a high sheer venturi reactor removed 81–92%. This value is varied based on the organic loading, where it ranged between 3 and 85 kg COD/m^3 d, where the solid retention time (SRT) is less than two hours and two days [50].

Nutrient Treatment. Yuan *et al.* concluded that the nitrification rate was reduced from 0.0595 mg NH_4/N g MLVSS to 0.0251 mg NH_4/N g MLVSS and dissolved oxygen concentrations from 4.5 to 1.0 mg/L within a sequencing batch reactor studying parameters such as dissolved oxygen, ORP, and pH. Overall, nitrification was able to be improved by high DO, while removing total inorganic nitrogen (TIN) [51].

Zeng *et al.* used a continuous anaerobic-anoxic-aerobic (A2O) process treating domestic wastewater where the nitrate accumulation rate was 90%, ammonia removal efficiency at 95%, where nitrification-denitrification occurred at both dissolved oxygen levels from 0.3 to 0.5 mg/L and 1.5 to 2.5 mg/L [52]. Guo *et al.* found that nitrogen removal with nitrate and simultaneous nitrification-denitrification indiciated that a sludge retention time of 50 to 66 days, dissolved oxygen of 0.65 mg/L, where nitrate accumulation was 95% [53].

Mourad *et al.* looked at a phosphate fertilizer plant in Egypt and found a relationship in phosphate within the wastewater affects the environment, by measuring Ra-226 and Th-232 isotope discharge [54]. Gouider *et al.* found a relationship between fluoride and phosphate removal, where fluoride was removed between 97 and 98% from a phosphoric acid/hydrofluoric acid and between 93 and 95% from a phosphoric/hexafluorosilic acid, as compared to 82% for phosphoric acid alone [55].

Beline *et al.* developed four types of biological reactors were capable of treating piggery wastewater that 60–70% nitrogen is removed by nitrification/denitrification. When additional mechanical separation was added for treatment, 80% of phosphorous was removed from soils along with the removal of pathogenic bacteria [56].

Dechlorination. Mezohegyi *et al.* discovered that using an upflow stirred packed-bed reactor with a biological activated carbon system was able to have a successful conversion rate of azo dyes. It was determined that an azo dye declorization model included heterogeneous catalysis and biological degradation [57].

Combined aerobic-anaerobic treatment. Sponza and Demirden discovered that in a sequential anaerobic baffled reactor and an aerobic completely stirred reactor, total COD (98%) and Kemicetine (100%) removal efficiency with real pharmaceutical wastewater. Also, acute toxicity was reduced across the reactors [58].

Kochany and Lipczynska-Kochany concluded that using aerobic and anaerobic industrial wastewater saw a higher removal of formaldehyde and phenol by anaerobic removal as compared to aerobic treatment, as anaerobic treatment ranged within 70%, while aerobic treatment was within the 40% range [59]. Yemashova *et al.* found a relationship with the decomposition of various azo dyes is determined by the conditions—anaerobic or aerobic conditions, the composition of the microbial community, and methods of reduction. Specifically, the methyl red was the only dye removed during aerobic conditions, as compared to anaerobic conditions was able to convert all dyes present [60].

Lopez *et al.* was capable of using both coagulation and flotation with the coagulant being alum and anionic polymer as flocculent for treating slaughterhouse wastewater. Removing efficiency was 94% when using 250 mg/L alum, 51 mg/L of polymer, with a pH of 4. This is compared with the biological process using an anaerobic filter (AF) and sequencing batch reactor (SBR) where COD ranged 50–81%, configured with optimum removal was 97% for hydraulic retention time (HRT) 20 h in the AF and 9 h in the SBR [61]. Abreau and Zaiat found that using an upflow anaerobic-aerobic reactor where the anaerobic reactor had an HRT of 10 h and COD reduction from 389 to 137 mg/L. Using a combined, COD removal went from 259 to 93 mg/L with an HRT of 12 h (6 h of anaerobic and 6 h of aerobic [62].

5. Anaerobic Treatment

Anaerobic/anoxic reactors, filters. Lin *et al.* found that using oxic-anoxic fixed biofilm reactors (FBR) with porous ceramic sticks and plastic rings for swine wastewater, had a removal efficiency increase to 86–92% for NH_4-N from 56-98% removal, when the ammonia nitrogen loading rate increased from 0.25 kg NH_4-N/m^3 d from 0.082 kg NH_4-N/m^3 d. Also, the authors observed 82% denitrification by means of bacteria and 98–100% of removal occurred in the denitrifying part of the FBR, where NO_2-N was 2 mg/L and NO_3-N 6 mg/L [63].

Puyol compared anaerobic degradation of 2,4-dichlorophenol among both an upflow anaerobic sludge blanket (UASB) and an expanded granular sludge with glucose, and determined that the loading rates determined the overall removal of 2,4-dicholorophenol (2,4-DCP) was higher in the UASB than the EGSB with efficiency rates of 75 and 84% respectively [64]. Satyanarayan *et al.* noticed that using the upflow anaerobic sludge blanket process is capable of treating herbal pharmaceuticals by removing COD (range 86.2–91.6%), BOD (90.0–95.2%), and SS (62.6–68.0%, It was determined that using the system is capable of treating high strength wastewater within a six month time frame [65].

Freine *et al.* found that by using an anaerobic fluidized bed reactor removal was 92% when the pentachlororphenol (PCP) concentration was 1 mg/L and 70% for 6 mg/L, having considered pH, alkalinity, COD, and volatile acids. Treatment was within a 16 L reactor and completed using granular activated carbon [66]. Behera *et al.* found that an upflow anoxic bioreactor could removed COD and NO_3-N where nitrification by ethanol was 78 to 98% as compared to tapioca starch which removed a ranged between 68 to 96% for removal [67].

Microorganism Presence. Ahn *et al.* studied a sequencing batch reactor and noticed that there is a relationship between organic loading the F/M relationship, as increasing organic loading increased F/M. In addition, the amount of *Rhodocyclus* bacteria counts peaked at low loading rates [68]. El-Gohary and Tawfik found by using coagulation/flocculation and sequencing batch reactor processes that the optimum parameters include color removal, pH, magnesium chloride and lime concentration. In addition, COD, BOD, and TSS were removed at efficiencies greater than 61% [69]. Guo *et al.*, using a temperature of 30°, pH between 6.0 and 8.5, and percent NaCl of 10–20% for wastewater treatment using *Halomonas Sp.* strain bacteria to treat using azo dye wastewater. Azo dye treatment found decholorination at 90% with a treatment time of 24 h [70].

Ebrahimi *et al.* used two bubble column sequencing batch reactors with artificial wastewater at 20, 30, and 35° Celsius. Determination was made in the first stage that *Lepothrix spp*was present at 30 °C, while 20° acetate was consumed in anaerobic condition and biological phosphorus removal by *Rhodocyclacae*-affiliating OUT 14 at 30 and 35° Celsisus acetate was completed and phosphorus removal did not occur as high [71].

Anaerobic-aerobic, biosporption, digestion. Kim *et al.* used a sequencing anoxic/anaerobic-aerobic membrane bioreactor for 60 days where it was capable of having high efficiency removal of COD, TN, TP, with the values greater than 70%. Included the authors were capable of removing estrogenic compounds bisphenol A and 2,4-dicholorophenol [72].

Nagda *et al.* studied batch experiments, concluding the removal of Tendu leafe Diospyros melanoxylon within industrial waste treatment was capable of being adsorbed with the combination of biosorption and hydrogen peroxide. In addition, the authors concluded that the adsorption was favorable and could be summarized using Freundlich and Langmuir isotherms as similar to Congo red adsorption [73].

6. Air Emissions

Separation. Isolongifolene was converted from isolongifolene by means of membrane based air separation with oxygen enriched air were the derivative was related to reaction temperature and oxygen-enabled air, as observed by Wu *et al.* Maximum yield occurred was 39.1% and a temperature of 60° Celsius. This minimized effluent discharge [74].

Model. Vijayaraghavan *et al.* concluded that through a three-dimensional Eulerian Community Multiscale Air Quality Model (CMAQ) for coal-fired power plants and emission of nitrates and sulfates in southeastern United States at the Escambia Bay and the watershed model on the Florida-Alabama border. The results indicated an effect on the concentration of nitrates and sulfur dioxide control on nitrogen deposition can be combined by the results of the nitrates and sulfates on oxidized nitrogen and reduced nitrogen species [75]. Corsi and Lin developed a model based on the component within latex paint, 2,2,3-trimethyl-1,3-pentanediol monoisobutyrate, compiling past history on emissions, recovery and factors affecting the process, and information on models describing the emissions [76].

Lopez-Torres and Llonens found that treating organic fraction municipal solid waste , 11.5% COD was solubilized, using a loading rate of 0.15 m^3 CH$_4$/kg volatile solids, removed soluble COD of 93.0% and 94% when treating using an anaerobic digester and lime addition Ca(OH)$_2$ chemical pretreatment [77]. Whitcombe *et al.* found that using a fluidized bed model (FBR) with a Fluidized Catalytic Cracker Limit (FCCU) on a 1:8.5/ system. A conclusion was poor correlation between emission rates predicted, where this was done without the estimation of volatilization and flocculation for total emissions since it was able to achieve particle emission [78]. Gao *et al.* conducted a model known as backwards Lagrangian Stochestic Model (LSM) for methane emissions from multiple sources on a farm. The model consisted of C1, ground level sources, three wind-flow disturbances; C2, three sources with different emissions; C4, ground level and two elevate4d sources. The results found that the model provides accurate [79].

Biofilter. Cheng used a biological aerated filter with a fixed-film process, removed volatile organic compounds such as toluene, trimethylbenzene from a multiple layer ceramic capacitor manufacturing plant, and determined that 90% COD was removed, including a 30–40% toluene was aerated [80].

7. Soils and Groundwater

Soil Washing. Villa *et al.* found that by using solar photo-Fenton processes within 6 h, 99% DDT , 95% DDE, and 100% diesel removed; using Triton-X-100, removal was 66% DDT, 80% DEE, and 100% diesel. All metals Pb, Cr, Ni, Cu, Cd, Mn, and Co where below the Brazilian legislation wastewater concentrations [81]. Goi and Trapido were able to degrade chlorophenols up to

80% by using soil remediation at natural soil pH with calcium and magnesium peroxide. The authors found that this soil remediation process was comparable to application of hydrogen peroxide [82].

Adsorption. Xu *et al.* discovered that pharmaceuticals and personal care product (PPCPs) removal by adsorption was under Freundlich isotherms. Degradation within four US agricultural soils provided a trend where the PPCPs were removed within first-order exponential decay kinetics. In addition, the authors noted that the degradation that occurred within the system was in relation to the chemical composition within the soil, as higher rates of degradation occurred with lower chemical concentrations [83]. Zhang *et al.* found that the use of polymeric adsorption in aqueous solutions where the matrix of acrylic ester resin and functional groups determined the mechanism of adsorption. Also, the authors found high adsorption was contingent on high specific area and intense micropore structure [84]. Fan and Zhang found that using heat treatment for waste treatment of organic dyes was capable of removing alkaline-black were parameters: pH and adsorbentdose. Dye removal follows Langmuir adsorption isotherm model [85]. Niinane found that using chelating (S,S,S)-ethylenediominedisuccinc acid (EDDS) for electrokinetic process, and ethylenediaminetetraacetic acid (EDTA) and citric acid for soil washing, was capable of removing 50% of lead by means of soil washing and citric acid. However, using electrokinetics, EDTA was better at removing than EDDS [86].

Degradation performance (biodegradation), microorganisms. Jechalke *et al.* used coconut fiber and polypropylene textiles to treat benzene, methylene tert-butyl ether (MTBE), and ammonium by using a time of 14 months of operation. The results found that benzene was reduced from 20 mg/L to 1 µg/L MTBE 4 mg/L to 1.2 mg/L, and ammonium went from 59 mg/L to 56 mg/L, where the microorganisms used the coconut fiber and polypropylene textiles for degrading biofilms [87].

Beler-Baykal and Allar determined that using real and simulated fertilizer wastewater (using clinoptilolile) is capable of being used for the purpose of removing ammonium, where it was determined that ammonium removal was contingent on pH and contact times. Ideally, the authors were able to obtain surface capacities of greater than 14 mg NH_4-N/g clinoptilolite with empty bed contact times greater than 10 min [88]. Wang *et al.* discovered that mixed microbial indigenous bacteria are capable of biodegrading diesel and crude oil, n-alkanes, and polyaromatic hydrocarbons in the Yellow River Delta. The parameters affected were temperature, salinity, pH, and Carbon:Nitrogen:Phosphorus (C:N:P) ratio [89].

Surfactants, Fe(zero valence Fe). Reinsch *et al.* found that nanoscale zerovalent iron (ZVI) applied to 10 mM anions Cl^-, NO_3^-, SO_4^{2-}, HPO_4^{2-}, HCO_3^-, and 9 mg/L dissolved oxygen. From the experiment, 1 month aging anions were dissolved by NZVI, 6 months was results showed all anions dissolved except nitrate, where 1 month had Fe and $FeSO_4^{2-}$, and 6 months had $Fe_3(PO_4)_2$ $8H_2O$ (viviante) and iron sulfate , and $(Fe_{16})_3 + O_{16}$ $OH, SO_4(12–13, (10–12)H_2O$ [90].

Thompson *et al.* used nanoscale zero-valent iron to degrade alachior herbicide and determined that a surface area of 25 m^2/g was sufficient, while a surface area between 1–2 m^2/g surface area constants were 38.5×10^{-5} and $3.8–7.7 \times 10^{-5}$ L/hm^2 [91]. Noubactep *et al.* compared the shaking intensity under various conditions for the purpose of discoloring methylene blue with metallic iron, where it was determined that the materials considered were scrap iron, granular activated carbon, and deep sea manganese nodules. From fifty days of experimentation, discoloration of methylene blue is related to shaking intensity, where the peak shaking intensity is 50 min^{-1} [92].

Liu *et al.* was capable of degrading 2,2,',4,4'-tetrabromodiphenye ether (BDE, 47) consisting of soil-washing and photodestruction processes within non-ionic surfactants under UV-irradiation at 253.7 nm. From considering concentration, pH, cation and acetone, it was found that the results followed pseudo-first-order kinetics, where pH is varied because of the cations and acetone [93].

***In situ* applications.** Lim and Lynch found that using a photocatalytic reactor was capable of designing in an in-situ groundwater remediation, and having five successful experiments, a hydraulic retention time (HRT) of 1 day, average water velocity of 0.21 m/d for high efficiency of using this particular design [94].

Other methods, models. Chen *et al.* discusses a mathematical model that transports reagent within vertical circulation flow within an anisotropic aquifer for the purpose to enhance groundwater remediation in an anisotropic aquifer with vertical circulation well technology. The following methods are used—analytical solution for steady state drawdown near a vertical circulation well, radial and vertical components are applied to 3-D axismetrical advection dispersion in cylindrical coordinates [95].

Lin *et al.* considered a simulated biotreatment process specifically biostimulation and bioagumentation with oxygen-related reactive barriers (ORRB) and water. The authors discovered that benzene, toluene, ethylene, zylene (BTEX) remove decreases at a concentration of 30 mg/L, where ORRB removal was higher for nitrogen-added for biostimulation, specifically oxygen content was inversely proportion to the distance from ORRB [96].

Davie *et al.* found that trichloroethylene (TCE) removal (500 to 1200 mg/L) at Edwards Air Force Base in California was at 99.8% at 4 h when considering catalytic reductive dechlorination (CRD) for groundwater pumped at 2 gal/min, hydrogen concentration of 0.35 mg/L with 2–3 min pumping and a 20 kg shell, a pH of 7 on aluminum bed with a 2% by weight [97]. Finzger and Lestan considered soil remediation using EDTA for leaching and electrochemical advanced oxidation (EAOP) and soil rinsing, using a boron dipped anode removed 44% Lead (Pb), 14% Zinc (Zn), and 55% Cadmium (Cd) from the soul. The results found optimum at pH of 7.73, 13.74 Pb, Zn 1007 mg/kg, and Cd 9.1 mg/kg [98].

8. Reuse

Photocatalysis. Sanchez *et al.* found that grey water, waste produced from hotel wastes, where the reuse was capable of obtaining 65% dissolved organic removal after 150 min by the application of photocatalysis over titanium dioxide. Specific constituents include ionic surfactants from personal care products and laundry detergents [99]. Zho and Zhu compared the treatment efficiency of various advanced oxidation processes (UV/O_3, UV/TiO_2, and UV/TiO_2/O_3) using laboratory scale recirculation ozonation photocatlytic system. Ozone and the photocatalytic process (UV/TiO_2/O_3) is more efficient in TOC removal for TOC, where one must consider ozone dose and ozone procedure had a higher impact than UV intensity, incoming ozone flow rate, and UV light source [100]. Riera-Torres *et al.* found that when comparing nanofiltration using a 0.5 L membrane at 10 bar, *versus* coagulation-flocculation with anionic polyelectrolyte flocculant and $FeCl_3$ as a coagulant, and melamine-urea-formaldehyde and polyamine resins, 40–80% of color in 5 dyes was removed, as compared to using coagulation-flocculation which removed 85–95% color within 4 dyes [101].

RO-IE (reverse osmosis/ion exchange), membranes. Yangali-Quintanilla *et al.* found that nanofiltration and reverse osmosis was capable of being strong treatment for pharmaceuticals, pesticides, endrocrine disruptions, and organic compounds, removing 82% by nanofiltration and 85% by reverse osmosis. Ionic compound removal was discovered at 97% and 99% by nanofiltration and reverse osmosis respectively [102]. Zhu and Zou used activated carbon with TiO_2 nanoparticles with a sol-gel method and concluded that photocatalytic process was able to decompose compounds by means of using H_2O_2 and ultrasound. The components considered using UV light source, UV irridiation, hydrogen peroxide and ultrasound constituent [103].

Authors Bellona *et al.* compared the efficiency of using both an ultralow pressure reverse osmosis (ULPRO) and ultrafiltration both at pilot scale and full-scale in California. The conclusion from the tests based on operation, total organic carbon (TOC), total nitrogen (TN), and regulated and unregulated organic pollutants was that the treatment process did meet water quality requirements [104]. Juang *et al.* found that a membrane-based ultrafiltration and reverse osmosis process was capable of completely adhering to water standards for tap, cooling, and boiling water, and feed water for a purification machine. When treating mechanical polishing wastewater. However, when UF pretreatment only removed 42–46.9% conductivity, 98.1–99.4% turbidity, and 4.5–24.5% TOC, while RO only reduced conductivity to 6 mu S/cm, 0.01 NTU, and 1.6 mg/L TOC [105].

Dialysis, sludge reuse. Vertova *et al.* found elctrodialysis for treating light carboxylic acids from an acidic waste stream. In addition, the authors determine that the use of electrodialysis is a sustainable alternative to biological degradation [106].

Kim *et al.* concluded that using O_3, UV/H_2O_2, and O_3/UV treatment processes with pharmaceuticals and personal care products and it was shown that using O_3/UV and UV/H_2O_2 treatments are recommended and also profitable due to the issues of bromated formation that occurs when using ozone [107]. Bello *et al.* completed a study where a sewage treatment plant with aeration, an activated sludge and compost water treatment within metallurgic industry. Parameters investigated include pH, turbidity, color, aerobic bacteria, free chlorine, hardness, alkalinity, chloride, sulfates, and dissolved total solids (TDS) for the purpose of removing biological oxygen demand (BOD), chemical oxygen demand (COD), and suspended solids (SS) [108].

Disinfection. When using disinfection in grey water, authors Winward *et al.* discovered that particle-associated coliforms (PAC) having come into contact with chlorine disinfection show that the 91% of the total coliforms were particle related, where the disinfection efficiency was based on particle size. Those PAC were not removed due to larger-sized particles shielding them from being removed [109].

9. Summary

Over the last three years there have been various new treatment methods that have been used. For example, nano-alumina, PS-EDTA, and beta-cyclodetrin are some of the new materials for sorption. Several authors introduced new methods of treatment, which include a new biological and electrochemical (BEO) treatment within physicochemical method using boron-diamond electrodes for pesticide wastewater, and ion exchange usage for treating zirconium radioactive waste. Ozone has been effective in various realms of treatment—removing organic compounds, pharmaceuticals, and

dyes. Nitrification-denitrification and sequencing batch reactor remains a popular method of treating nutrients and dometic wastewater respectively. Adsorption is a commonly used method for dyes, pharmaceuticals, and heat transfers. Finally, treatment of grey water is significant due to its ability for reuse by various industries. Treatment of grey water varies using various photocatalysis methods—ultraviolet (UV), ozone (O_3), and hydrogen peroxide (H_2O_2), membrane process (nanofiltration, ultrafiltration, and reverse osmosis), and electrodialysis.

10. Conclusion

While this is not an all-encompassing text for the last three years, this summary does provide an opportunity to consider what treatment methods are being used within subjects surrounding waste handling and reuse related to wastes from chemicals and allied products. As many technological advances have been made to consider more effective methods, future research will be employed for the purpose of improving current methods or proposing new methods beyond the scope of what is currently and readily available.

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