Chapter 10
Recycling and Reuse of Ayurvedic Pharma Industry Wastes

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Abstract Ayurvedic medicines are of great importance to the health of individuals. The global market for herbal drugs are growing rapidly due to their less or no side effects, cost-effectiveness, availability, better patient tolerance, and clinical effectiveness. The traditional ayurvedic medicine manufacturing systems combine with the elements of modern technology to improve the production of reasonable drugs for human health care. Globally, ayurvedic pharma industries are among the leading pharmaceutical industries and they generate large volume of biodegradable wastewater, solid waste, and oil waste during processing and production. The waste from herbal pharmaceutical industry is a complex constitute of plant extracts, plant parts, toxic solutes, and heavy metal ions. They also have high BOD and COD concentrations so they can be discharged only after proper treatment otherwise may lead to environmental problems. Integrated microbial-vermifiltration, vermicomposting, and windrow composting are some of the cost-effective methods for the recycling of solid waste from herbal pharmaceutical industry. Microalgae are used for the treatment of waste water due to their potential to reduce the metal contamination and remove toxic substances. The resultant water after the treatment was clean enough to be reused for irrigation process. Biopharmaceutical oil waste and solid waste can be used also as substrate for fermentation process as well as for isolation of beneficial fungal strains for enzyme production.

Keywords Ayurvedic medicines · Herbal pharmaceutical waste · Integrated microbial-vermifiltration · Vermicomposting · Windrow composting

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10.1 Introduction

Ayurveda is a traditional medicinal system which was originated and shaped in the ancient lands of India. The term Ayurveda is a combination of two Sanskrit words: "Ayu," which means life and "veda" means knowledge. Thus the literal meaning of ayurveda is "The science of life." This oldest medicinal system was thought to have originated in the Vedic times around 5000 years ago. The primary focus of ayurveda is to heal and maintain the quality and longevity of life (Kumar et al. 2016; Raj et al. 2011). Various types of ayurvedic medicines are used for the human health care. They are herbal teas, decoctions, infusions, capsules and powders, tinctures, infused oils, ointments, creams, lotions, arishtas (fermented decoction), and asavas (fermented infusions), etc. Arishta, asava, churna, rasayana, and taila are some of the examples of conventional drugs of ayurveda. These products are mainly composed of herbal combinations and minerals. Alcoholic preparations such as arishtas and asavas are made by allowing the herbal juices/decoctions to go through the fermentation process with the addition of sugar. These alcoholic medicaments have several advantages, like enhanced therapeutic effectiveness, better shelf life, and improvement in the productivity of extraction of drug molecules from the herbs (Sekar and Mariappan 2008). Plants are the essence of ayurveda and approximately 90% of herbal preparations are plant based. Therefore, the plant-based formulations play a vital role in the ayurvedic healing process. Most of the ayurvedic medicinal preparations are polyherbal, with a combination of 3–30 plants involved. Ayurvedic plants have a stronger action on the body than either food or spices. Plants have chemical compounds known as phytochemicals, which are naturally occurring and biologically active. These are used as traditional medicines in ayurvedic treatments (Kumar et al. 2017).

Ayurveda is considered as science of healthy life which is based on the principle of maintaining a balance between the interrelated relationships within the body and mind. Ayurvedic medicines aid to interconnect the body's constitution and mind (Kumar et al. 2016). Using these concepts, ayurvedic physicians prescribe individualized treatments, including compounds of herbs, diet, exercise, and lifestyle recommendations. According to World Health Organization (WHO), 65–80% of World's population depends on traditional medicine to promote good health and prevent illness (Sasidharan et al. 2011; Das et al. 2016). Ayurvedic medicine is one of the world's popular and oldest healing system and the demand for herbal drugs was increased many folds at the global level. This is mainly due to the adverse impact of synthetic drugs. Herbal medicines do not have any side effects and proved to be safe for long-term use. Cost-effectiveness and relative ease of availability make herbal medicines a popular choice among treatment for various diseases (Kumar et al. 2016). Therefore, people are now moving toward traditional herbal-based medicinal system. Other factors such as clinical effectiveness, better patient tolerance, and reduction in offensive factors have also helped to gaining the popularity of herbal medicines. The global market for herbal drug is increasing rapidly (Das et al. 2017). Herbal medicines are usually thought to be safe due to its natural origin.

However, the plants used for preparation of herbal drugs should be evaluated by modern scientific methods because case reports indicate that serious side effects and pertinent interactions with other drug can appear altering physiology and these changes can be reflected in abnormal test results. Evaluation of herbal plants helps to demonstrate their usefulness and to avoid the use of useless and toxic herbs (Khan et al. 2016). Ayurveda has two basic aims; first, to preserve the health of healthy person and second is to treat illness and disease. In this sense, there are two types of medicines in Ayurveda; those which promote resistance and vitality of the body and those which cure disease (Shroff 2017).

The ayurvedic traditional preparations comprise medicinal plants, minerals, organic matter, etc. Many drugs are developed with phytochemicals or taking phytochemicals as active principle (Inamdar et al. 2008). In most countries, complex mixtures of one or more plants, which are used for the preparation of standardized herbal medicines for the management of various diseases. These are known as phytotherapeutic agents or phytomedicines. WHO recognized that active ingredients from plant parts or plant materials in the crude or processed state plus certain excipients, i.e., solvents, diluents, or preservatives are the main ingredients of herbal drugs. Usually, the active compounds responsible for their pharmacological action are unknown. One of the main characteristics of phytotherapeutic agents is the fact that they normally do not possess an immediate or strong pharmacological action. Due to this reason, phytotherapeutic agents are not used for emergency treatment. However, herbal medicines possess wide therapeutic use and greater acceptance by the population. The standardized preparations of herbal drugs are normally available in the market as liquid, solid (powdered extract), or viscous preparations. They are prepared by different extraction methods such as decoction, maceration, percolation, or distillation (for volatile oils). Fluid extracts are mainly prepared by using ethanol, water, or mixture of ethanol and water. Solid or powdered extracts are produced by evaporation of the solvents used in the process of extraction of the raw material. The concentrated phytotherapeutic agents have much more better therapeutic efficacy (Calixto 2000).

10.2 Ayurvedic Pharma Industry Wastes

The manufacturing process is one of the key steps in herbal pharmaceutical industry. During the production of herbal drugs using plant parts, such as roots, stems, nuts, barks, seeds, flowers, and fruits, creates large amount of solid wastes. Wastes from ayurvedic pharmacies are mainly organic in nature. Different kinds of wastes are produced from the ayurvedic industries, such as solid waste, wastewater, medicinal oil, etc. Pharmaceutical industries are one of the highly polluting types of industries among the others and they generate strong and high Chemical Oxygen Demand (COD) wastewater along with hazardous waste (Das et al. 2017).

10.3 Solid Wastes

Solid wastes generated during the processing and production of herbal medicines are enormous in volume and need proper treatments before the disposal, otherwise may cause environmental problems. Huge quantities of spent wastes are produced during the manufacturing of ayurvedic products, which are recalcitrant in nature. The manufacturing process of herbal pharmaceutical medicines involves the washing (cleaning) of herbs viz.; flowers, roots, stems, leaves, barks, nuts, fruits, seeds, tubers, leaves, and resins to remove the dust and soil adhered to the material. Herbs are dried after this cleaning and subjected to cutting or powdering through ball mills as per the requirement. In decoction preparation, a portion of the cleaned plant parts is boiled in water for specific time. After decoction preparation plant parts are generated as solid waste. This solid waste is very sharp, hard, and thorny in nature and it cannot be used as animal feed. The dried solid waste also cannot be used as a fodder (like leguminous plants), because of the very sharp and prickly nature. The solid wastes from ayurvedic industries are recalcitrant in nature. So it is important to develop a better technique for reducing the environmental issues associated with these wastes (Das et al. 2017). Ayurvedic pharma industries (processing units and product manufacturing units) produce a large quantity of spent wastes after pre-processing and/or distillation or extraction of active principles from raw materials. So this can be considered as an emerging pollutant for terrestrial environment. If proper treatment and disposal are not made, the solid waste generated from these herbal manufacturing industries create issues of all types of environmental pollution and spoil esthetic sense of local habitats. Different steps involved in production of ayurvedic medicines and generation of both solid and liquid waste are shown in Fig. 10.1.

Inappropriate disposal of plant-origin wastes pose serious environmental effects. In majority of cases these wastes are just dumped openly either at landfill sites or at open space nearby to industrial areas, but this method is not a proper way for disposal. This will lead to the nutrient enrichments in surface water bodies, emission of greenhouse gasses, nitrate leaching to groundwater, proliferation and breeding of disease vectors, etc. The best options for sustainable solid waste management programs are recycling, reuse, and resource.

10.3.1 Vermicomposting

Composting is a decomposition process of organic matter by microorganisms under controlled conditions. Fungi, actinomycetes, protozoa, nematodes, annelids, arthropods, etc. are examples of decomposers or detritus feeders available in nature, which have the capacity to decompose the complex organic substances of wastes as well as enhance the quality of end products. Recycling of organic wastes generated from different sectors of human society can be done with the help of earthworms.

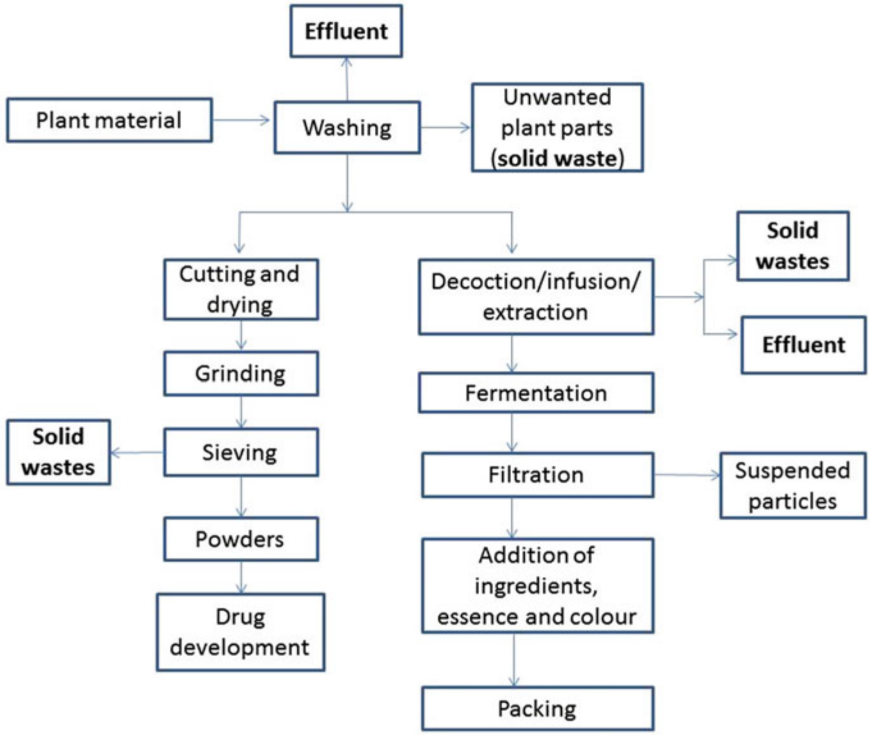

Fig. 10.1 Schematic representation of the production of ayurvedic medicines and generation of waste

Table 10.1 Different categories of earthworms

Earthworm species	Characteristics
Epigeics (humus feeders)	Surface dwelling nature
Anecics (geophytophagous)	Soil dwelling nature and construct vertical tunnels
Endogeics (geophagous)	Soil dwelling organisms which construct horizontal branching burrows

Earthworms are considered as potential decomposer and utilization of earthworms for waste decomposition is called vermicomposting (Singh and Suthar 2012). The growth of earthworms in organic wastes has been termed vermiculture, while the processing of organic wastes by earthworms is known as vermicomposting. Table 10.1 represents the details of three main categories of earthworms.

The epigeics are most suited to vermicomposting (Abbasi et al. 2009). Widely used earthworms for vermicomposting include *Megascolex mauritii*, *Eisenia fetida, Eudrilus eugeniae, Perionyx excavatus, Lampito mauritii, Eisenia andrei, Lampito rubellus*, and *Drawida willis* (Manyuchi and Phiri 2013). In vermicomposting, stabilization of organic material is achieved through the joint action of earthworms and microorganisms. Microorganisms are involved in the biochemical degradation of organic matter. And the earthworms play an important role, which drives the whole process, preparing the substrate and altering the biological activity (Das et al. 2017). When compared to conventional thermophilic composting system, the vermicomposting has several advantages in terms of process time, nutrients recovery, microbial richness, and phytotoxicity. The operating conditions for traditional composting and vermicomposting methods are different. So the composted products from these composting methods are very different (Singh and Suthar 2012). Nowadays vermicomposting technology is mostly preferred because it accelerates the process and time taken for composting is reduced considerably. While the normal composting method takes longer time for stabilization. Another advantage of vermitechnology is the easy and efficient eradication of pathogens and toxic substances present in the substrates. Vermicomposting is an eco-friendly approach, which is based on soil-based beneficial microorganisms such as lactic acid bacteria, yeast, phototrophic bacteria, and naturally occurring microorganisms in soil and cattle dung, etc. Therefore, the substrate for vermicomposting generally mixed with cattle dung and garden soil and pre-decomposed before vermicomposting. In vermicomposting, cow dung was mainly used as vermibed or feed material for earthworms. In contrast to normal composting method, vermicomposting does not add exothermic reactions; so, there is no measurable rise in temperature in the vermireactors. During vermicomposting, an aerobic condition is maintained with the help of earthworms and the solids in the organic waste are ingest and convert them into vermicast. Vermicomposting increases the manurial value of waste and also reduces the total volume and particle size of the biomass waste. Moreover, the presence of micro- and macronutrients is usually higher in vermicompost than in the traditional compost and inorganic fertilizers. So vermicompost is a better supplement to stimulate plant growth (Das et al. 2017; Abbasi et al. 2009). Vermicompost is an odorless, dark brown bio-fertilizer resultant after the vermicomposting process (Manyuchi and Phiri 2013).

Solid waste from herbal pharmaceutical industry mainly consists of large size stalks, stems, leaves, barks, tubers, nuts, and roots. Hence it chopped before subjecting it to vermicomposting. So the waste material was cut into small pieces is the first step in vermicomposting. However, too fine pieces are not suitable as they get compacted. Size reduction will induce fast vermicomposting, thus the vermiconversion time period is reduced. Das et al. (2017) investigated the vermicomposting of recalcitrant solid waste from herbal pharmaceutical industry. In this study, solid waste collected from a herbal pharmaceutical industry is subjected to routine physicochemical analysis and heavy metal analysis as per the standard methods. Then this recalcitrant solid waste was dried in shade, cut into smaller pieces, and used for the vermicomposting process. Cattle dung was also dried in shade before its use and the earthworm species used was *Eudrilus eugeniae*. Herbal industry solid waste, cattle dung, and soil were mixed in 1:1:1 ratio and kept for pre-decomposition. This pre-decomposed waste was then placed into earthenware vermibeds and 15 numbers of earthworms were introduced in it. The beds were kept in shade away from direct sunlight and rainwater entry and the beds were sprinkled with water to maintain the moisture content. Das et al. (2017) found that the resultant vermicompost of herbal pharmaceutical solid waste depicted efficient porosity of 80.487%, water holding capacity of 87.5534%, bulk density was around 0.9667 gm/cm^3, and the moisture content was around 18.6%, i.e., well within the applicable range. These results show that the resultant vermicompost is suitable for agricultural activity. The study concluded that herbal pharmaceutical waste is a good substrate with high percentage of volatile solids of total solids demonstrating its degradable nature. Hence it can be easily vermicomposted.

Kumari et al. (2011) selected *Eudrilus eugeniae* species of earthworm, for vermicomposting of herbal industry waste. *Eudrilus eugeniae* is an epigeics or humus feeding earthworm, can tolerate temperatures ranging from 0 to 40 °C. This species of earthworm is extensively used for the vermicomposting because of its voracious appetite, high rate of growth, and reproductive ability. Waste used for this study is a mixture of various remains of medicinally important herbs after industrial operation and the vermibeds were made using a mixture of herbal waste and cow dung (1:1) in comparison with the use of cow dung alone as substrate. Industrial waste used in this study comprises different medicinally important plant species (Table 10.2).

Kumari et al. (2011) found that resultant vermicompost, from the vermibed which contain both herbal waste and cow dung as substrate, strongly influenced the growth of pea (*Pisum sativum*) and marigold plant (*Tagetes erectus*).

Singh and Suthar (2012) used the solid waste from the herbal pharmaceutical industry that was a mixed type and containing spent material after extraction/ distillation of herbs and unused part of the plant. They used *Eisenia fetida* for vermicomposting process. In majority of previous studies *E. fetida* was used as candidate species for vermicomposting process because it can tolerate wide range of pH, temperature, and moisture. It can also stand for a wide range of putrescible substances and bio toxic compounds. In this study, the herbal pharmaceutical industrial waste (HPIW) was collected from spent material disposing unit of The Himalaya Drug Company, Dehradun which is one of the leading herbal pharmaceutical product manufacturing or processing unit in India. The waste was of mixed type mainly constituting spent material after extraction/distillation of herbs and unused part of the plant. The waste mixture acts as bedding as well as feed for the composting earthworms. For vermicomposting experimentation, Singh and Suthar

Table 10.2 Important constituents of industrial waste

Plant species	Parts	Percentage (%)
Punica granatum	Fruit	24
Aegle marmelos	Fruit	22
Woodfordia fruticosa	Flowers	14
Berberis aristata	Root	13.5
Symplocus racemosa	Bark	12
Andrographis paniculata	Stem	10
Salmalia malabarica	Bark	3.5

(2012) used 300 g waste mixture (dried material) was filled in plastic circular containers. The waste mixtures were moistened with distilled water to maintain moisture content for initial decomposition of waste mixtures. For the initiation of microbial degradation and softening of waste mixture, these bedding were kept for 1 week. In this study, 20 earthworms were collected from the stock culture and released into each different container containing 300 g of substrate material for vermicomposting. The moisture content (55–65%) was maintained throughout the experiment by periodic sprinkling of sufficient quantity of water. The experimental containers were placed in a humid and dark place at room temperature. The samples (homogenized) were collected at 0, 10, 20, 30, 40, 50, and 60 days from each container and these samples were subjected to measure the changes in chemical characteristics of waste mixture during vermicomposting. Singh and Suthar (2012) found that the earthworm caused significant changes in the chemical characteristics of waste mixtures during vermicomposting process. The resultant worm-worked material was more stabilized, odor free, and dark brown substance with high range of plant available forms of soil nutrients. After the vermicomposting process, there was significant reduction in pH value of all waste mixtures. The results of this study clearly suggest that HPIW may be a valuable source of nutrients for sustainable land restoration program if proper technology is applied to recover the valuable nutrients from such industrial wastes. The product showed significant increase in all chemical characteristics of wastes and C:N also reduced up to its acceptable limit for agronomic uses. Singh and Suthar (2012) suggested that vermicomposting can be an efficient and better tool to convert the noxious community wastes into value-added products for sustainable human development.

Vermicompost and vermiwash are rich in nitrogen (N), phosphorous (P), potassium (K), and trace elements. Their potential use as bio-fertilizers has been investigated in many studies as well as their impact on soil properties. Vermiwash is a leachate that is obtained during the vermicomposting process and is dark brown in color which is also known as liquid-bio fertilizer. So vermiwash can also be used as a foliar spray because it acts as a pesticide in sustainable agriculture. The vermicomposts are also termed as vermicasts because they are expelled as casts from the earthworm gut (Manyuchi and Phiri 2013; Manyuchi 2013). Manyuchi and Phiri (2013) investigated the effects of vermicompost and vermiwash on various plants such as cow pea, soy bean, maize, and marigold. They found that vermicompost and vermiwash influence the growth of plants. Vermicomposting results in earthworms, vermicompost, and vermiwash as products. The vermiproducts can be used as bio-fertilizers while the earthworms can be used for further vermicomposting.

10.3.2 Windrow Composting

One of the most commonly used methods of composting is the windrow process. Windrow composting operation is relatively simple and requires little attention other than monitoring temperature and moisture, which involves stacking organic wastes into long windrows that are turned periodically. Haq et al. (2016) studied the recycling of herbal pharmaceutical solid waste (HPSW) by windrow composting process for its conversion into a value-added product. Resultant composting material showed a pH 7.4 which was within the suitable limit 6.9–8.0 and hence the application of these products to soil may support the soil microflora. The C: N ratio decreased rapidly and stabilized to 10.42, which indicated the good biological stabilization and the application of the compost to cropping systems. They found that the windrow composting method is an environmental friendly approach, in which the recycling of herbal pharmaceutical solid waste produces an acceptable, nontoxic, and nutrient-rich substrate for agronomic purposes. This process also reduces pollution with respect to the wastes from ayurvedic pharma industry.

10.3.3 Spent Black Pepper: A Thrown Away Residue

Large scale production of ayurvedic herbal drugs generates significant quantities of processed wastes. The yield and purity of piperine isolated from spent black pepper (*Piper nigrum* L.) was studied by Rakesh et al. (2015). Piperine is a major constituent of black pepper and the first amide isolated from genus Piper, possesses diverse pharmacological activities including central nervous system depressant, antipyretic, analgesic, anti-inflammatory, and antioxidant properties. Several studies reported that piperine enhances digestive power and appetite and also play a role in healing cold and cough, dyspnoea, disease of throat, colic, dysentery, etc. (Vyas et al. 2011). Rakesh et al. (2015) used spent black pepper for their study. It is a "thrown away residue" from ayurvedic industry and these spent materials are important to their value-added components. In traditional ayurvedic medicinal system, the fruits of black pepper are commonly used. In this study, the spent pepper collected from a major ayurvedic industry has been screened for the presence of high-value volatiles, active principles, and extracts and they found that these contain 1.0–2.5% of volatile oil, 5–9% of alkaloids. Among which piperine, chavicine, piperidine, and piperetine are major biologically active compounds. In this study, the complete chemical evaluation of essential oil, oleoresin, and piperine recovered from both raw and spent black pepper was performed and the results obtained were lead to the conclusion that piperine content and purity were not much affected by conventional ayurvedic processing. Hence, this spent residue can be further processed for recovering such value-added products. Change in the concentration of aromatic constituents clearly supported that essential oil from spent pepper has commercial value close to that of raw pepper. This study helps to find out a better pathway for the utilization of thrown away residue from ayurvedic industries.

10.4 Liquid Waste

Ayurvedic industries generate a large volume of wastewater during processing and production. The moderately concentrated wastewater from these industries is biodegradable in nature and possesses high value of BOD (Biochemical Oxygen Demand), COD, and total solids. Due to the high strength, and acidic nature of wastewater, it cannot be discharged directly into the surface water, as they putrefy very fast and lead to environmental complications. Untreated pharmaceutical wastewater discharged into the natural environment leads to health hazards to existing flora and fauna. Therefore, treatment of the effluents is required to bring down the concentration of pollutants to suitable limits, before they are finally discharged into the natural systems. Hence, a treatment methodology is required which is easy to operate and can be easily accepted by the local ayurvedic manufacturing units (Vyas et al. 2011; Vanerkar et al. 2015). Herbal pharmaceutical wastewater is moderately strong with COD, BOD, and Suspended Solids (SS) concentration in the range of 21,960–26,000 mg/L, 12,200–15,660 mg/L, and 5460–7370 mg/L, respectively. Physicochemical treatment using conventional coagulants in combination with anionic/cationic/nonionic polyelectrolyte is one of the treatment technologies, which seemed viable for the reduction of organic load in the herbal pharmaceutical wastewater. An attempt has been made to study in detail the treatment of the herbal wastewater using conventional coagulants individually, in combination and also with the addition of anionic/cationic/nonionic polyelectrolyte. The complete treatability study of herbal pharmaceutical wastewater by suitable combination of primary physicochemical, secondary, biological aerobic suspended-growth activated-sludge process, and tertiary advanced oxidation process was done by Vanerkar et al. (2013). They found that Fenton's oxidation method is highly suitable to treat the herbal pharmaceutical wastewater as compared to radiation-induced hydroxyl radical generation processes. In Fenton's oxidation process, hydroxyl radicals can be introduced into the wastewater mixture in any concentration, at any rate, simply by varying the quantity of H_2O_2 and other catalyst, thus making it a much more versatile tool.

10.4.1 Integrated Microbial-Vermifiltration Technique

The use of earthworms as bio-filters in wastewater treatment is known as vermifiltration (Manyuchi and Phiri 2013). Nowadays integrated microbial-vermifiltration technology is used for the treatment of ayurvedic liquid effluents. In this technology, ayurvedic effluent was pretreated with a microbial consortium and later fed to a vermifiltration unit. Das et al. (2015) mainly focused on the development of treatment methods for ayurvedic liquid effluents by integrating microbial pretreatment and vermifiltration. *Eisenia fetida* earthworms were used for this study, which was collected from the composting units of Kerala Agricultural University (KAU), Mannuthy. Liquid effluents were collected from ayurveda industry and protease and lipase producing strains were isolated from these effluents by using standard plating techniques. A protease (*Bacillus* sp.) and lipase (*Bacillus* sp.) producing strains were selected for their study. Removal of oil portion from the effluent was done by using broken brick pieces of different sizes which were filled in a column and the effluent was passed through the column at a minimum flow rate. In this study, the bedding material for vermicomposting was mainly consisting of cow dung, straw, and vegetable scraps, which are used after suitable sterilization and placed in the uppermost layer of vermicompost. Vermifiltration is an extension of vermicomposting and also known as lumbrifiltration. Dissolved and suspended solids get trapped in the vermifilter bed and then they are digested by complex biodegradation process. Both aerobic and anaerobic microbes present in the soil also promote the degradation of organic and inorganic matter from the waste. Microbial-based degradation process and vermiculture-based process were found to work simultaneously in the treatment of domestic as well as industrial wastewater. In this study, ayurvedic effluent was treated with protease and lipase producing strain (*Bacillus* sp.) and also with a mixture of protease and lipase producing strains. After inoculation, they were incubated at 37 °C at 100 rpm in rotary shaker for 72 h. This pretreatment mainly focused on the protease and lipase action which helps in degradation of proteins and lipids present in the effluent and make it readily available for consumption by microbes and earthworms. The results from their study mentioned that organic matter in liquid effluent was significantly reduced during the treatment with enzymes and microbes. Thus, BOD level for vermifiltration process also decreased. Das et al. (2015) found that organic wastes, solids, and heavy metals are ingested and absorbed through earthworm's body wall and degraded. BOD, COD, total dissolved solids (TDS), and the total suspended solids (TSS) from wastewater were removed by this action and there was no sludge formation in the process. The resultant water was found to be odor free, clean, and disinfected enough to be reused for irrigation. In this study, the final vermifiltered water showed a significant reduction in COD by 98.03%, BOD by 98.43%, TSS by 95.8%, TDS by 78.66%, and oil and grease by 92.58%. Based on these results, they concluded that integrated microbial-vermifiltration technology is a decentralized and cost-effective method which can be applied to treat both domestic and industrial wastewater. A drastic reduction in different effluent parameters, such as BOD, COD, TDS, TSS, Oil and grease, was observed in this study. Pretreatment of effluent with bacterial consortium at optimum conditions showed maximum reduction in the above mentioned parameters. The resulting vermifiltered water is clean and disinfected enough to be reused for irrigation purpose.

10.4.2 Electrocoagulation

Electrochemical techniques are helpful for prevention and remedy pollution problems due to strict environmental regulations. Electrocoagulation (EC) process is a simple and efficient method for the treatments of various industrial wastewaters.

When compared to the conventional methods, the electrocoagulation process possesses some advantages such as easy to operate, less retention time, lower operating costs, absence of adding chemicals, rapid sedimentation of the electrogenerated flocs, and less sludge production and requires a simple equipment. Usually, biological methods are mainly used for the treatment of ayurvedic wastewater. Harshananda and Neera (2017) study the effectiveness of electrocoagulation on ayurvedic pharmaceutical wastewater. In this study, the optimum conditions obtained for EC treatment were pH 6, time 60 min, electrode gap of 0.5 cm, and current density 119.65 A/m^2 and the corresponding COD removal is of 90%. Though the COD removal percentage is high, the effluent COD value does not satisfy disposal standards. The BOD removal rate is also relatively low. Hence they concluded that electrolytic treatments are suitable only as a pretreatment for ayurvedic pharmaceutical wastewater. It can also be observed that the addition of electrolyte to reactor volume increases the treatment efficiency to a certain extent. Harshananda and Neera (2017) concluded that electrocoagulation provides high turbidity removal and also effective in the removal of dissolved matter by charge neutralization and electrostatic interaction.

10.4.3 Treatment of Wastewater Using Algae

Treatment of wastewater using algae for reducing the chemical and organic load has been studied for over 50 years. They are also capable of reducing the metal contamination in aquatic systems. Vanerkar et al. (2015) analysed the various physicochemical characteristics such as pH, COD, BOD, total solids, sodium, potassium, and heavy metals for the judgment of toxicity of herbal pharmaceutical wastewater after its treatment with micro green algae *Scenedesmus quadricauda*. When compared with the conventional tertiary treatment procedures, algal treatment of wastewater can offer an ecologically secure, cheap, and efficient way to remove nutrients and metals. Treatment of effluent by algae is mainly mediated through a combination of nutrient uptake, elevated pH, and high dissolved oxygen concentration. Physicochemically treated effluent (PCTE) and biologically treated effluent (BTE) of herbal pharmaceutical industry were used for this study. Tests for growth, survival rate, and synthesis of metabolites in PCTE and BTE using *S. quadricauda* were conducted. *S. quadricauda* is a common freshwater species of the chlorophycean group, widely distributed in subtropical parts of India. *S. quadricauda* is a good pollution indicator because it is sensitive to polluted wastewater; hence they selected it for their study. These are mainly occurring in canals, rivers, lakes, reservoirs, and other watersheds. In this study, detoxification test was performed for different wastewater concentrations (20, 40, 60, 80, and 100%) of untreated, physically treated, and biologically treated wastewater. Cultured *S. quadricauda* algae were added into different wastewater concentrations and incubated for 21 days. After completion of the incubation period, optical density (OD) was measured at 660 nm using a spectrophotometer to find biomass. The growth rate of *S. quadricauda* in

PCTE gradually increased throughout the incubation in 10, 20, and 30% dilution and no growth of *S. quadricauda* was found in 40–100% dilution of PCTE. Results showed that algae can remove toxic substances by accumulation, absorption, extracellular secretion, and enzymatic degradation. Algae can slowly utilize the herbal pharmaceutical wastewater as nutrient source and make it available for reuse. Vanerkar et al. (2015) concluded that, if a suitable algae like *S. quadricauda* is added to natural discharge of pharmaceutical wastewater, it will help in reducing the toxicity and facilitate recycling and reutilization of polluted water. They also highlighted that, differential tolerance of this microalga to the effluents shows that there is great scope for industrial wastewater treatments.

10.5 Medicinal Oil Waste

The biopharmaceutical oil waste is used as a substrate for fermentation and it also acts as a source of microorganisms for enzyme production. These roles help to minimize the environmental problems associated with biopharmaceutical oil waste. The usage of biopharmaceutical oil waste, on the one hand, provides good and alternative substrate for enzyme production and, on the other hand, helps in solving pollution problems. Oil rich waste from biopharmaceutical industry can use as substrate for lipase production. A comparative study of lipase enzyme yields by solid state fermentation (SSF) and submerged fermentation (SmF) was performed by Mohanasrinivasan et al. (2009). Lipases, one of the prominent industrial enzymes, act over a wide range of pH and temperature. It possesses high specificity, does not require cofactors, and can catalyze a wide range of reactions. In this study, three fungal colonies were isolated from biopharmaceutical oil waste. These wastes were collected from "Oushadhi" (The Pharmaceutical Corporation (IM) Kerala Ltd). More than 450 products were manufactured from this industry and which include asavas, arishttas, dhravams, choornams, khashayas, thailas (medicated oil), and chyavanaprasams, etc. The manufacturing steps of these ayurvedic products produce a vast amount of waste materials both oily and non-oily. The present study utilized biopharmaceutical oil waste as substrate for SSF which consisted of plant matter containing cellulose, medicinal oil, etc. The fungal strains were also isolated from this substrate (oil waste). After incubating the substrate in the open air environment for a week, the substrate containing plate was showed the growth of fungal strains. The pure colonies from these oil containing wastes were then used as inoculums for both solid state and submerged fermentation of lipase enzyme. The three fungal strains were identified as *Aspergillus* sp., *Trichoderma* sp., and *Penicillium* sp. In SSF, the oil waste itself was used as a substrate and it was enriched with $(NH_4)_2SO_4$ 5.0 g/l; Na_2HPO_4 6.0 g/l; KH_2PO_4 2.0 g/l; $MgSO_4.7H_2O$ 3.0 g/l; and $CaCl_2$ 3.0 g/l at pH 6. The production media (pH 6) used for SmF manily includes glucose-10, peptone-20, NaCl-5, and yeast extract-5 (g/l). Mohanasrinivasan et al. (2009) found that enzyme yields were higher in SSF when compared with SmF. They concluded that utilization of biopharmaceutical oil waste, on the one hand, provides alternative substrate and, on the other hand, helps in solving pollution problems.

10.6 Conclusion

Ayurveda is a comprehensive science and the ayurvedic medicines are important to the human health care system. The rapidly growing trends in herbal drugs lead to the development of ayurvedic industries. Ayurvedic pharmaceutical industries have become the major contributors to water pollution nowadays. Biological as well as chemical methods are available for reducing the negative effects of ayurvedic pharma industrial wastes in environment. Vermicomposting, vermifiltration, and windrow composting can be used as herbal pharmaceutical waste management strategy and at the same time these techniques access bio-fertilizers which are environmentally friendly. Vermicomposting results in earthworms, vermicompost, and vermiwash as products. The vermiproducts can be used as bio-fertilizers while the earthworms can be used for further vermicomposting. The resulting effluent from vermifiltration becomes highly nutritious and can be reused for irrigation purpose. Biopharmaceutical oil waste can be used as substrate as well as for isolation of beneficial fungal strains for enzyme production. Wastewater treated by electrocoagulation gives clear, colorless, and odorless water.

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