INDUSTRIAL WASTE MANAGEMENT: BRIEF SURVEY AND ADVICE TO COTTAGE, SMALL AND MEDIUM SCALE INDUSTRIES IN UGANDA

AWUCHI CHINAZA GODSWILL
Department of Biological and Environmental Sciences,
School of Engineering and Applied Sciences,
Kampala International University,
Kampala, Uganda.

IGWE VICTORY SOMTOCHUKWU
Department of Food Science and Technology,
Federal University of Technology Owerri,
Imo State, Nigeria.

INTRODUCTION

Cottage, small and medium scale industries in developing countries account for large share of employment and, in most cases, production. Recent growth of these classes of industries has been in response to high labour availability and low financial resources in most of these developing countries.

However, the urban management program of UNCHS (Habitat), together with World Bank, UNDP, and other collaborating agencies, have pointed out the general lack of technical-know-how and adequate knowledge on waste management regarding the cottage, small and medium scale industries and their relative impact on the environment.

The definition of micro (cottage), small and medium enterprises includes all types of enterprises irrespective of their legal form (such as family enterprises, sole proprietorships or cooperatives) or whether they are formal or informal enterprises to ensure inclusiveness (MTIC, 2015). A cottage industry has within 1 to 4 employees, small scale 6 to 50, medium scale 50 to 300, and large scale >300 employees.

Wastes are unwanted or unusable materials. Waste is any substance which is discarded after primary use, or it is worthless, defective and of no use. The term is often subjective (because what is waste to one need not necessarily be waste to another) and sometimes objectively inaccurate (for example, to send scrap metals to a landfill is to inaccurately classify them as waste, because they are recyclable). Examples include municipal solid waste (household trash/refuse), hazardous waste, wastewater (such as sewage, which contains bodily wastes (feces and urine) and surface runoff), radioactive waste, and others.

The main sources of wastes in some African countries like Uganda are households, markets, institutions, streets, public areas, commercial areas and manufacturing industries (Kaseva & Mbuligwe, 2005). Waste generation in Uganda is between 1.2 and 3.8 kg/day, low income 0.3 kg/capita/day and high income 0.66 kg/capita/day (James and Richard, 2011). There is often indiscriminate waste disposal without concern for human health impacts or environmental degradation. The problems of waste management are compounded by the rapid urban population growth caused by rural to urban migration overstretching resources (Yhdego, 1995). Municipal wastes constitute one of the most crucial public health and environmental problems in African cities (Achankeng, 2003; Adebilu & Okenkule, 1989; Rotich, Yongsheng, & Jun, 2006). Industrial waste contributes to most of the sources environmental pollution in Uganda.

In Uganda like in many other developing countries, typically one to two thirds of the waste generated is not collected (Zerbock, 2003). As a result, the uncollected waste, which is often also mixed with human and animal excreta, is dumped indiscriminately in the streets/wards and in drains, contributing to flooding, breeding of insect and rodent vectors and the spread of diseases such as cholera.

Industrial waste is the waste produced by industrial activity which includes any material that is rendered useless during a manufacturing process such as that of factories, industries, mills, and mining operations. It has existed since the start of the Industrial Revolution. Some examples of industrial wastes are chemical solvents, paints, sandpaper, paper products, industrial by-products, metals, and radioactive wastes.

Most researchers, have linked Waste generation directly to the size of population and the various activities undertaken by different categories of the population including large scale industries, small-scale industries, trading/businesses, municipal, farming, household, schools, among others. Hence, it clearly means that waste generation will increase with increasing population growth (ibid).

In Kampala alone, waste generation estimations have been rated at 0.2 metric tons per person annually on average (Ngategize et al., 2001). Therefore, considering an urban population of 3.7 million people that is; 13.4% of the total population (Uganda Population secretariat, 2007), it means that approximately 740,000 metric tons of solid waste are generated in urban areas per year. Of this, only 41% solid waste generated is disposed off properly (UNDP, 2005). The remaining 51% is left uncollected thereby ending up dumped in drainage and sanitary drainage channels, natural water courses, manholes, undeveloped plots and road sides among other unfit places (NEMA, 2004).

Where avoidance of waste generation seems to be inevitable, some techniques, such as brine treatment, may be adopted to reduce effects of waste on environment.

***Figure 1**: Uganda is a landlocked country in East Africa whose diverse landscape encompasses the snow-capped Rwenzori Mountains and immense Lake Victoria. Its abundant wildlife includes chimpanzees as well as rare birds. Adequate attention is yet to be given to industrial waste from MSME.*

LEARNING OUTCOMES

After reading this guiding information in this article, it is expected that cottage, small and medium scale industries in Uganda:

- Are aware of the additional sources of guidance and support that are available to them, for proper waste management.
- Can appreciate the environmental and legislative importance of managing wastes in their industries.
- Have an awareness of the broad range of risk and environmental issues that might impact their industries and host communities.
- Have a broad understanding of the key aspects of waste management, especially the waste management options of reduction, reuse, recycling and disposal.
- Can identify potential areas within their business that may be able to reduce waste production, optimize recycling, and curb environmental pollution.
- Can develop a waste disposal strategy for their organization; among others.

INDUSTRIAL WASTE MANAGEMENT

Wastes are unwanted or unusable materials. Waste is any substance which is discarded after primary use, or it is worthless, defective and of no use.

The term is often subjective (because what is waste to one need not necessarily be waste to another) and sometimes objectively inaccurate (for example, to send scrap metals to a landfill is to inaccurately classify them as waste, because they are recyclable). Examples include municipal solid waste (household trash/refuse), hazardous waste, wastewater (such as sewage, which contains bodily wastes (feces and urine) and surface runoff), radioactive waste, among others.

Industrial waste is the waste produced by industrial activity which includes any material that is rendered useless during a manufacturing process such as that of factories, industries, mills, and mining operations. It has existed since the start of the Industrial Revolution. Some examples of industrial wastes are chemical solvents, paints, sandpaper, paper products, industrial by-products, metals, and radioactive wastes. Other categories of waste include residential, commercial wastes, among others.

RISK ASSESSMENT IN INDUSTRIAL WASTE MANAGEMENT

Cottage, small and medium scale industries in Uganda should be aware residents located near waste management units and sources of waste want to understand the management activities taking place in their neighborhoods. They want to know that waste is being managed safely, without danger to public health or the environment. This requires an understanding of the basic principles of risk assessment and the science behind it. Opportunities for dialogue between facilities, states, tribes, and concerned citizens, including a discussion of risk factors, should take place before decisions are made. Remember, in waste management, successful partnerships are an ongoing activity.

Risk assessment is a systematic process of evaluating the potential risks that may be involved in a projected (industrial waste management) activity or undertaking. Environmental risk communication skills are critical to successful partnerships between companies, state regulators, the public, and other stakeholders. As more environmental management decisions are made on the basis of risk, it is increasingly important for all interested parties to understand the science behind risk assessment. There are three major interconnected steps involved in carrying out risk assessment on industrial waste: hazard identification, exposure assessment, and risk characterization.

1. Hazard identification: identifying and characterizing the source of the potential risk (e.g., chemicals managed in a waste management unit). the source of the potential risk has already been identified: waste management units. However, there must be a release of chemicals from a waste management unit for there to be exposure and risk. Chemicals can be released from waste management units by a variety of processes, including volatilization (where chemicals in vapor phase are released to the air), leaching to ground water (where chemicals travel through the ground to a groundwater aquifer), particulate emission (where chemicals attached to particulate matter are released in the air when the particulate matter becomes airborne), and runoff and erosion (where chemicals in soil water or attached to soil particles move to the surrounding area). To consider these releases in a risk assessment, information characterizing the waste management unit is needed. Critical parameters include the size of the unit and its location. For example, larger units have the potential to produce larger releases. Units located close to the water table might produce greater releases to ground water than units located further from the water table. Units located in a hot, dry, windy climate can produce greater volatile releases than units in a cool, wet, non-windy climate.

2. Exposure assessment (Pathways, Routes, and Estimation): determining the exposure pathways and exposure routes from the source to an individual. Individuals and populations can come into contact with environmental pollutants by a variety of exposure mechanisms and processes.

The mere presence of a hazard, such as toxic chemicals in a waste management unit, does not denote the existence of a risk. Exposure is the bridge between what is considered a hazard and what actually presents a risk. Assessing exposure involves evaluating the potential or actual pathways for and extent of human contact with toxic chemicals. The magnitude, frequency, duration, and route of exposure to a substance must be considered when collecting all of the data necessary to construct a complete exposure assessment. The steps for performing an exposure assessment include identifying the potentially exposed population (receptors); pathways of exposure; environmental media that transport the contaminant; contaminant concentration at a receptor point; and receptor's exposure time, frequency, and duration. In a deterministic exposure assessment, single values are assigned to each exposure variable. For example, the length of time a person lives in the same residence adjacent to the facility might be assumed to be 30 years. Alternatively, in a probabilistic analysis, single values can be replaced with probability distribution functions that represent the range in real-world variability, as well as uncertainty. Using the time in residence example, it might be found that 10 percent of the people adjacent to the facility live in their home for less than three years, 50 percent less than six years, 90 percent less than 20 years, and 99 percent less than 27 years.

3. Risk characterization: In the risk-characterization process, the health benchmark information (i.e., cancer slope factors, reference doses, and reference concentrations) and the results of the exposure assessment (estimated intake or dose by potentially exposed populations) are integrated to arrive at quantitative estimates of cancer and non-cancer risks. To characterize the potential non carcinogenic effects, comparisons are made between projected intake levels of substances and reference dose or reference concentration values. To characterize potential carcinogenic effects, probabilities that an individual will develop cancer over a lifetime are estimated from projected intake levels and the chemical-specific cancer slope factor value. This procedure is the final calculation step. This step determines who is likely to be affected and what the likely effects are.

WASTE CHARACTERIZATION

Waste characterization is the process by which the composition of different waste streams is analyzed. Waste characterization plays an important part in any treatment of waste which may occur. Cottage, small and medium scale industries using new waste management technologies must take into account what exactly waste streams consist of in order to fully treat the waste. The biodegradable element of the waste stream is vitally important in the use of systems such as composting or anaerobic digestion.

Wastes classified as hazardous are considered to display one or more of the properties listed; one or more of the following characteristics:

— flash point ≤ 55 ºC,
— one or more substances classified (2) as very toxic at a total concentration ≥ 0,1 %,
— one or more substances classified as toxic at a total concentration ≥ 3 %,
— one or more substances classified as harmful at a total concentration ≥ 25 %,
— one or more corrosive substances classified as R35 at a total concentration ≥ 1 %,
— one or more corrosive substances classified as R34 at a total concentration ≥ 5 %,
— one or more irritant substances classified as R41 at a total concentration ≥ 10 %,
— one or more irritant substances classified as R36, R37, R38 at a total concentration ≥ 20 %,
— one substance known to be carcinogenic of category 1 or 2 at a concentration ≥ 0,1 %,
— one substance known to be carcinogenic of category 3 at a concentration ≥ 1 %
— one substance toxic for reproduction of category 1 or 2 classified as R60, R61 at a concentration ≥ 0,5 %,
— one substance toxic for reproduction of category 3 classified as R62, R63 at a concentration ≥ 5 %,
— one mutagenic substance of category 1 or 2 classified as R46 at a concentration ≥ 0,1 %,
— one mutagenic substance of category 3 classified as R40 at a concentration ≥ 1 %.

List of R-phrases

R-phrases (short for Risk Phrases) are defined in Annex III of European Union Directive 67/548/EEC: Nature of special risks attributed to dangerous substances and preparations. The list was consolidated and republished in Directive 2001/59/EC, where translations into other EU languages may be found.

These risk phrases are used internationally, not just in Europe, and there is an ongoing effort towards complete international harmonization.

Table 1: R-phrases (short for Risk Phrases) and their connotations.

Code	Phrase
R1	Explosive when dry
R2	Risk of explosion by shock, friction, fire or other sources of ignition

R3	Extreme risk of explosion by shock, friction, fire or other sources of ignition R4 Forms very sensitive explosive metallic compounds
R5	Heating may cause an explosion
R6	Explosive with or without contact with air
R7	May cause fire
R8	Contact with combustible material may cause fire
R9	Explosive when mixed with combustible material
R10	Flammable
R11	Highly flammable
R12	Extremely flammable
R14	Reacts violently with water
R15	Contact with water liberates extremely flammable gases R16 Explosive when mixed with oxidizing substances
R17	Spontaneously flammable in air
R18	In use, may form flammable/explosive vapour-air mixture
R19	May form explosive peroxides
R20	Harmful by inhalation
R21	Harmful in contact with skin
R22	Harmful if swallowed
R23	Toxic by inhalation
R24	Toxic in contact with skin
R25	Toxic if swallowed
R26	Very toxic by inhalation
R27	Very toxic in contact with skin
R28	Very toxic if swallowed
R29	Contact with water liberates toxic gas.
R30	Can become highly flammable in use
R31	Contact with acids liberates toxic gas
R32	Contact with acids liberates very toxic gas
R33	Danger of cumulative effects
R34	Causes burns
R35	Causes severe burns
R36	Irritating to eyes
R37	Irritating to respiratory system
R38	Irritating to skin
R39	Danger of very serious irreversible effects
R40	Limited evidence of a carcinogenic effect
R41	Risk of serious damage to eyes
R42	May cause sensitization by inhalation
R43	May cause sensitization by skin contact
R44	Risk of explosion if heated under confinement
R45	May cause cancer

R46	May cause inheritable genetic damage
R48	Danger of serious damage to health by prolonged exposure
R49	May cause cancer by inhalation
R50	Very toxic to aquatic organisms
R51	Toxic to aquatic organisms
R52	Harmful to aquatic organisms
R53	May cause long-term adverse effects in the aquatic environment
R54	Toxic to flora
R55	Toxic to fauna
R56	Toxic to soil organisms
R57	Toxic to bees
R58	May cause long-term adverse effects in the environment
R59	Dangerous for the ozone layer
R60	May impair fertility
R61	May cause harm to the unborn child
R62	Possible risk of impaired fertility
R63	Possible risk of harm to the unborn child
R64	May cause harm to breast-fed babies
R65	Harmful: may cause lung damage if swallowed
R66	Repeated exposure may cause skin dryness or cracking
R67	Vapours may cause drowsiness and dizziness
R68	Possible risk of irreversible effects

Source: Annex III of European Union Directive 67/548/EEC.

MATERIALS AND METHODS

A project group was set up to study the waste management system in most of the cottage, small, and medium scale industries in some districts. Range of methods involving companies' inspection, residents' interviews, questionnaires, observations, and document reviews, as well as literature reviews, to obtain quantitative and qualitative data were used. Four companies, each from western, northern, eastern and central Uganda, were selected for the study. Human issues related to waste management were explored and feedback used to communicate the extent of environmental pollution, as a result of poor waste management. Selection of companies was systematically done by review of companies' profiles and records, as regards to waste management.

Waste characterisation and quantification, as well as risk analysis, were done following standard procedures whereby likely hazardous compounds and substances were identified and mitigating measures suggested. The impacts of solid waste on environment were recorded through visual examination of all the stages of solid waste management and by interviewing stakeholders. Data collected were scientifically examined.

RESULTS AND BRIEF DISCUSSIONS

Some research works were randomly conducted in Sugar Corporation of Uganda Limited (SCOUL), Rwenzori Water Company, Kakira Sugar Works, and Mukwano Industries Limited, with some results discussed below.

In some sugar manufacturing factories, such as SCOUL, the bagasse, a residue left after juice extraction from sugar cane is first dried in hot oven, burnt and used as fuel to boil water and steam generation. Also, the bagasse is used to turn the turbine that will generate electrical power. And the ash, after combustion, is mixed with filtered cake (mud) that is further used as manure or fertilizers in crop production.

By burning of bagasse, fine dark particles, together with CO and other carcinogenic substances, are released. Due to the lack of adequate facility to prevent or reduce the amount of these particles released in air, they constitute air pollution within the factory and surroundings. This affects heath of people within the radius of the pollution.

> *NB: To prevent this air pollution the chimney that discharges the smoke from the furnace to the environment should be equipped with* ***filter*** *that will trap these particles.*

In effluent treatment, the waste products from the fermentation and distillery sections contain various organic matters which are toxic and unfriendly to both the environment and also to the human health when disposed to the environment or inhaled by human.

To avoid such dangers, there is need to treat those waste products before releasing them to the environment. The waste treatment process always leads to the formation of some compounds – methane (CH4), carbon dioxide, hydrogen sulfide – through anaerobic fermentation. Waste water which has BOC and pH with the tolerable range is disposed to the environment

The **methane** generated is usually voluminous, yet the capacity of the plant is too small to contain it. Some methane escapes into the atmosphere, contributing to greenhouse gas emission.

> *NB; to prevent this, the excess methane has to be compressed and store in a cylinder for cooking, heating, among others.*

The **hydrogen sulfide,** whose fraction in the total waste product is usually within 2-3%, corrodes pipes and affects the skin and metal capacity.

> *NB; the hydrogen sulfide can be used in the synthesis of sulfur dioxide (in the presence of Oxygen) which is a bleaching agent used in some industrial processes.*

$$2H_2S + 3O_2 \longrightarrow 2SO_2 + 2H_2O$$

Generally, study shows poor industrial waste management in most of the cottage, small, and medium scale industries in Uganda, which may be attributed to lack of technical-know-how in proper waste management, negligence of hazardous nature of waste and its negative impact on environment, inadequate training and development, among.

In kampala, Wakiso, Entebbe, Kalunga, and other districts in Uganda, most cottage, micro, small and medium industries practice inadequate waste water and solid waste management.

ADVICE TO COTTAGE, MICRO, SMALL, AND MEDIUM ENTERPRISES ON TECHNIQUES TO USE FOR EFFICIENT WASTE MANAGEMENT SYSTEM IN UGANDA

There are two major levels of waste treatment: *primary and secondary levels.* Tertiary level is considered advanced and more sophisticated level. Advice will be based mostly on primary and secondary levels of waste treatment and management.

Primary treatment involves separating a portion of the suspended solids from the wastewater. Screening and sedimentation usually accomplish this separation process. *Secondary treatment* involves further treatment of the effluent. The effluent from primary treatment will ordinarily contain considerable organic material and will have a relatively high Biological Oxygen Demand (BOD). Biological processes generally accomplish the removal of the organic matter and the residual suspended solids. The effluent from secondary treatment usually has little BOD (30 mg/l as average) and a low suspended solids value (30 mg/l as average) (Metcalf and Eddy, 1991).

Some readily and moderately degradable compounds and substances are shown in table 1.

Table 1. Biodegradability of organic hazardous waste (Leachy & Brown, 1994)

Readily degradable	Moderately degradable	Recalcitrant
Gasoline	Crude oil	TCE
Jet fuel	Lubricating oils	PCE
Diesel fuel	Coal tars	Vinylchloride
Toluene	Cresotes	PCB
Benzene	Pentachlorophenol	DDT
Isopropylalcohol	Nitrophenol	Chlordane
Methanol	Aniline	Heptachlor
Acetone	Long-chain aliphatics	
Phenol	Phthalates	
Ketone		

WASTE REDUCTION TECHNIQUES

Industries should aim at source reduction, recycling and/or waste treatment.

Source Reduction means any practice which reduces the amount of any substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment, prior to recycling, treatment, or disposal; and reduces the risks to public health and the environment associated with the release of such substances, pollutants, or contaminants. Where source reduction is not obtainable, recycling should be considered.

Recycling requires an examination of waste streams and production processes to identify opportunities. Recycling and beneficially reusing wastes can help reduce disposal costs, while using or reusing recycled materials as substitutes for feed stocks can reduce raw materials costs. Materials exchange programs can assist in finding uses for recycled materials and in identifying effective substitutes for raw materials. Recycling not only helps reduce the overall amount of waste sent for disposal, but also helps conserve natural resources by replacing the need for virgin materials. Where recycling is not obtainable, adequate waste treatment, followed by disposal, should be considered.

Treatment can reduce the volume and toxicity of a waste. Reducing a waste's volume and toxicity prior to final disposal can result in long-term cost savings. There are a considerable number of levels and types of treatment from which to choose. Selecting the right treatment option can help simplify disposal options and limit future liability.

INDUSTRIAL WASTE TREATMENT TECHNIQUES

Treatment of non-hazardous industrial waste is not a federal requirement; however, it can help to reduce the volume and toxicity of waste prior to disposal. Treatment can also make a waste amenable for reuse or recycling.

Cottage, small and medium scale industries in Uganda can use one (or combination) of some of the waste treatment techniques explained hereinafter to reduce environmental pollution and increase efficient waste management system.

Treatment involves changing a waste's physical, chemical, or biological character or composition through designed techniques or processes. There are three primary categories of treatment— physical, chemical, and biological.

Physical treatment involves changing the waste's physical properties such as its size, shape, density, or state (i.e., gas, liquid, solid). Physical treatment does not change a waste's chemical composition. One form of physical treatment, immobilization, involves encapsulating waste in other materials, such as plastic, resin, or cement, to prevent constituents from volatilizing or leaching. Few examples of physical treatment include Immobilization, Filtration, Carbon absorption, Distillation, Evaporation/volatilization, Grinding, Shredding, etc.

Chemical treatment involves altering a waste's chemical composition, structure, and properties through chemical reactions. Chemical treatment can consist of mixing the waste with other materials (reagents), heating the waste to high temperatures, or a combination of both. Through chemical treatment, waste constituents can be recovered or destroyed. Listed below are a few examples of chemical treatment. Few examples of chemical treatment include Neutralization, Oxidation, Reduction, Precipitation, Acid leaching, Ion exchange, Incineration, Thermal desorption, Extraction, etc.

Biological treatment can be divided into two categories–aerobic and anaerobic. Aerobic biological treatment uses oxygen-requiring microorganisms to decompose organic and non-metallic constituents into carbon dioxide, water, nitrates, sulfates, simpler organic products, and cellular biomass (i.e., cellular growth and reproduction). Anaerobic biological treatment uses microorganisms, in the absence of oxygen, to transform organic constituents and nitrogen-containing compounds into oxygen and methane gas ($CH_{4(g)}$). Anaerobic biological treatment typically is performed in an enclosed digester unit. Few examples of biological treatment include;

• Aerobic:
Activated sludge
Aerated lagoon
Trickling filter
Rotating biological contactor (RBC)
• Anaerobic digestion

Some of these treatment techniques listed above, together will other treatment techniques, are discussed below:

Ion exchange chromatography

Ion exchange can be used for the removal of undesirable anionic and cationic substances from a wastewater. Cations are exchanged for hydrogen or sodium and anions for hydroxyl ions. Ion exchange resins consist of an organic or inorganic network structure with attached functional groups. Most ion exchange resins used in wastewater treatment are synthetic resins made by the polymerisation of organic compounds into a porous three-dimensional structure. Ion exchange resins are called *cationic* if they exchange positive ions and *anionic* if they exchange negative ions. Cation exchange resins are comprised of *acidic* functional groups, such as sulphonic groups, whereas anion exchange resins have *basic* functional groups, such as amine. The strength of the acidic or basic character depends upon the degree of ionisation of the functional groups, similar to the situation with soluble acids or bases. Thus, a resin having sulphonic acid groups would act as a strong acid cation exchange resin. For the other types of ion exchange resins, the most common functional groups are carboxyl (-COOH) for weak acid, quaternary ammonium (R3N+OH-) for strong base, and amine (-NH2 or -RNH) for weak base.

Oil and grease separation (Flotation)

In oil separation, free oil is floated to the surface of a tank and then skimmed off. The design of a gravity separator is based on the removal of all free oil globules larger than 0.15 mm. The Reynolds number is less than 0.5, so Stokes' law applies. Typically, effluent oil concentrations in the order of 50 mg/l are achieved. The hydraulic loading of a cross-flow corrugated plate separator (Figure 19.3) varies with temperature and the specific gravity of the oil. Nominal flow rates are specified for a temperature of 20 °C and a specific gravity of 0.9 for the oil. A hydraulic loading of 0.5 $m^3/m^2/h$ of actual plate area will usually result in separation of 0.06-mm droplets. Oil emulsions can be broken before separation by acidification, the addition of alum or iron salts, or the use of emulsion-breaking polymers.

Coagulation

Coagulation may be used for the clarification of industrial wastes containing colloidal and suspended solids. Paperboard wastes can be coagulated effectively with low dosages of alum. Silica or polyelectrolyte aids in the formation of a rapid-settling flock. Wastes containing emulsified oils can be clarified by coagulation. The oil droplets in water are approximately 10-5 cm and are stabilised by adsorbed ions. Emulsifying agents include soaps and anion-active agents. The emulsion can be broken by "salting it out" with the addition of salts, such as $CaCl_2$. A lowering of the pH of the waste solution can also frequently break an emulsion.

Precipitation – heavy metals removal

Precipitation is employed for removal of heavy metals from industrial effluents. Heavy metals are generally precipitated as hydroxide through the addition of lime or caustic (NaOH) to a pH of minimum solubility. The pH of minimum solubility varies with the metal in question. For example, the solubility of chromium and zinc are minimal at pH 7.5 and 10.2, respectively. When treating industrial wastewater that contains metals, it is necessary to pre-treat the effluents to remove substances that will interfere with the precipitation of the metals. Cyanide and ammonia form complexes with many metals, limiting the removal of them. For many metals such as arsenic and cadmium, co-precipitation with iron or aluminum is highly effective for removal to low residual levels. In order to meet low effluent requirements, it may be necessary to provide filtration to remove flock carried over from the precipitation process. Filtration should reduce effluent concentrations to 0.5 mg/l or less. For chromium wastes treatment hexavalent chromium must first be reduced to the trivalent state Cr^{3+} and then precipitated with lime. The reducing agents commonly used for chromium wastes are ferrous sulphate, sodium *meta*-bisulphite, or sulphur dioxide.

Brine treatment

Brine treatment involves removing dissolved salt ions from the waste stream. Although similarities to seawater or brackish water desalination exist, industrial brine treatment may contain unique combinations of dissolved ions, such as hardness ions or other metals, necessitating specific processes and equipment.

Brine treatment systems are typically optimized to either reduce the volume of the final discharge for more economic disposal (as disposal costs are often based on volume) or maximize the recovery of fresh water or salts. Brine treatment systems may also be optimized to reduce electricity consumption, chemical usage, or physical footprint.

Brine treatment is commonly encountered when treating cooling tower blow down, produced water from steam assisted gravity drainage (SAGD), produced water from natural gas extraction such as coal seam gas, frac flow back water, acid mine or acid rock drainage, reverse osmosis reject, chlor-alkali wastewater, pulp and paper mill effluent, and waste streams from food and beverage processing.

Brine treatment technologies may include: membrane filtration processes, such as reverse osmosis; ion exchange processes such as electro-dialysis or weak acid cation exchange; or evaporation processes, such as brine concentrators and crystallizers employing mechanical vapour recompression and steam.

Reverse osmosis may not be viable for brine treatment, due to the potential for fouling caused by hardness salts or organic contaminants, or damage to the reverse osmosis membranes from hydrocarbons.

Evaporation processes are the most widespread for brine treatment as they enable the highest degree of concentration, as high as solid salt. They also produce the highest purity effluent, even distillate-quality. Evaporation processes are also more tolerant of organics, hydrocarbons, or hardness salts. However, energy consumption is high and corrosion may be an issue as the prime mover is concentrated salt water. As a result, evaporation systems typically employ titanium or duplex materials.

Brine management

Brine management examines the broader context of brine treatment and may include consideration of government policy and regulations, corporate sustainability, environmental impact, recycling, handling and transport, containment, centralized compared to on-site treatment, avoidance and reduction, technologies, and economics. Brine management shares some issues with leachate management and more general waste management.

Solids removal

Most solids can be removed using simple sedimentation techniques with the solids recovered as slurry or sludge. Very fine solids and solids with densities close to the density of water pose special problems. In such case filtration or ultrafiltration may be required. Although, flocculation may be used, using alum salts or the addition of polyelectrolytes.

Oils and grease removal

The effective removal of oils and grease is dependent on the characteristics of the oil in terms of its suspension state and droplet size, which will in turn affect the choice of separator technology.

Oil pollution in water usually comes in four states, often in combination:

- free oil - large oil droplets sitting on the surface;
- heavy oil, which sits at the bottom, often adhering to solids like dirt;
- emulsified, where the oil droplets are heavily "chopped"; and
- dissolved oil, where the droplets are fully dispersed and not visible. Emulsified oil droplets are the most common in industrial oily wastewater and are extremely difficult to separate.

The methodology for separating the oil is dependent on the oil droplet size. Larger oil droplets such as those in free oil pollution are easily removed, but as the droplets become smaller, some separator technologies perform better than others.

Most separator technologies will have an optimum range of oil droplet sizes that can be effectively treated. This is known as the "micron rating."

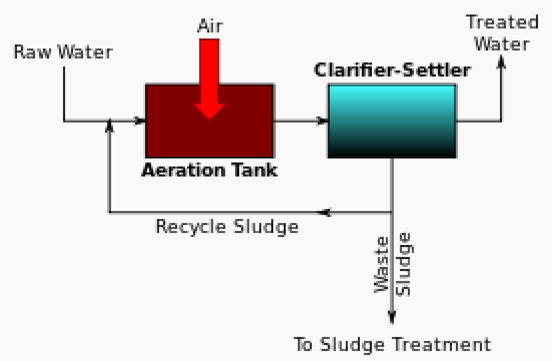
Analysing the oily water to determine droplet size can be performed with a video particle analyser. Alternatively, there are commonalities in industries for oil droplet sizes. Larger droplets greater than 60 microns are often present in wastewater in workshops, re-fuel areas and depots. Twenty to 50 micron oil droplets often are present in vehicle wash bays, meat processing and dairy manufacturing effluent and aluminum billet cooling towers. Smaller droplets in the range of 10 to 20 microns tend to occur in workshops and condensates.

Each separator technology will have its' own performance curve outlining optimum performance based on oil droplet size. The most common separators are gravity tanks or pits, API oil-water separators or plate packs, chemical treatment via DAFs, centrifuges, media filters and hydrocyclones.

Removal of biodegradable organics

Biodegradable organic material of plant or animal origin is usually possible to treat using extended conventional sewage treatment processes such as activated sludge or trickling filter. Problems can arise if the wastewater is excessively diluted with washing water or is highly concentrated such as undiluted blood or milk. The presence of cleaning agents, disinfectants, pesticides, or antibiotics can have detrimental impacts on treatment processes.

Activated sludge process



A generalized diagram of an activated sludge process.

Activated sludge is a biochemical process for treating sewage and industrial wastewater that uses air (or oxygen) and microorganisms to biologically oxidize organic pollutants, producing a waste sludge (or floc) containing the oxidized material. In general, an activated sludge process includes:

- An aeration tank where air (or oxygen) is injected and thoroughly mixed into the wastewater.
- A settling tank (usually referred to as a clarifier or "settler") to allow the waste sludge to settle. Part of the waste sludge is recycled to the aeration tank and the remaining waste sludge is removed for further treatment and ultimate disposal.

Trickling filter process

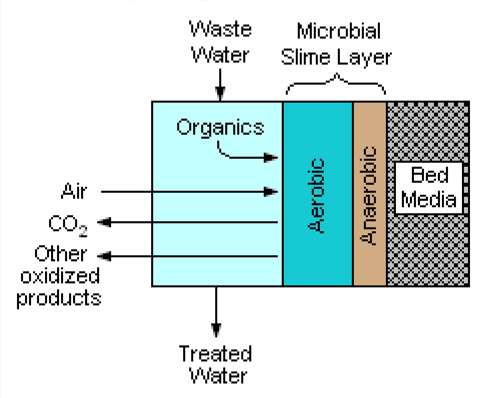
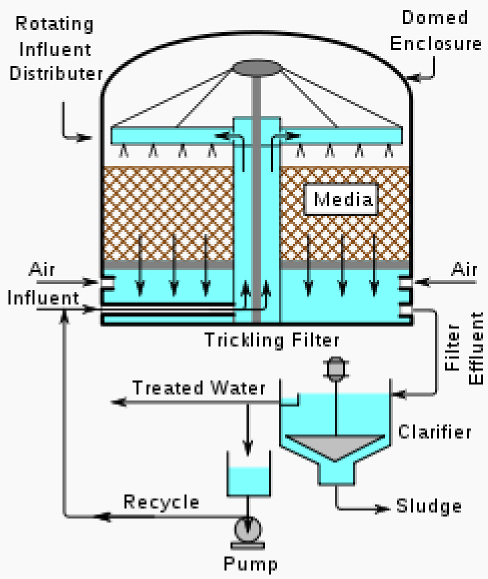


Image 1: A schematic cross-section of the contact face of the bed media in a trickling filter



A typical complete trickling filter system

A **trickling filter** consists of a bed of rocks, gravel, slag, peat moss, or plastic media over which wastewater flows downward and contacts a layer (or film) of microbial slime covering the bed media. Aerobic conditions are maintained by forced air flowing through the bed or by natural convection of air. The process involves adsorption of organic compounds in the wastewater by the microbial slime layer, diffusion of air into the slime layer to provide the oxygen required for the biochemical oxidation of the organic compounds. The end products include carbon dioxide gas, water and other products of the oxidation. As the slime layer thickens, it becomes difficult for the air to penetrate the layer and an inner anaerobic layer is formed.

The fundamental components of a complete trickling filter system are:

- A bed of filter medium upon which a layer of microbial slime is promoted and developed.
- An enclosure or a container which houses the bed of filter medium.
- A system for distributing the flow of wastewater over the filter medium.
- A system for removing and disposing of any sludge from the treated effluent.

The treatment of sewage or other wastewater with trickling filters is among the oldest and most well characterized treatment technologies.

A trickling filter is also often called a trickle filter, trickling biofilter, biofilter, biological filter or biological trickling filter.

CONCLUSION

The main sources of wastes in some African countries like Uganda are households, markets, institutions, streets, public areas, commercial areas and manufacturing industries. Waste generation in Uganda is between 1.2 and 3.8 kg/day, low income 0.3 kg/capita/day and high income 0.66 kg/capita/day (James and Richard, 2011). There is often indiscriminate waste disposal without concern for human health impacts or environmental degradation, especially from household, cottage, small and medium scale industries.

Cottage, small and medium scale industries in Uganda can use one (or combination) of some of the waste treatment techniques explained in this article to reduce environmental pollution and increase efficient waste management system. Treatment involves changing a waste's physical, chemical, or biological character or composition through designed techniques or processes. The three primary categories of treatment— physical, chemical, and biological – may be adopted for waste management to ensure sustainable green environment.

REFERENCES

Achankeng, E. J. (2003). Globalization, Urbanisation and Municipal Solid Waste Management in Africa. In Proceedings of African Studies Association of Australasia and the Pacific: African on a global stage.

Adebilu, A. A., and Okenkule, A. A. (1989). Issues on environmental sanitation of Lagos mainland Nigeria. The Environmentalist, 9(2), 91 – 100.

Ayres, R.U and L. Ayres, (1996) Industrial ecology - towards closing the materials cycle Cheltenham: Edward Elgar p.1

Cochran, W. G. (1977). Sampling techniques (3rd ed.). Wiley.

Florida Department of Environmental Protection: Solid Waste Section. (1995). Municipal Solid Waste Land fill Alternate Design Closure Guidance.

Fowler, J., Cohen, L., and Jarvis, P. (1998). Practical statistics for field biology (2nd ed.). John Wiley and Sons.

Geosynthetic Research Institute. (1990). Landfill Closures: Geosynthetics Interface Friction and New Developments. GRI Proceedings.

Grefe, R. P. (1989). Closure of Papermill Sludge Lagoons Using Geosynthetics and Subsequent Performance. Presented at the Twelfth Annual Madison Waste Conference. September.

Heath, Jeffrey H. 1996. "Landfill Closures: Balancing Environmental Protection with Cost," MSW Management. January/February. pp. 66-70.

http://www.environmentagency.gov.uk/subjects/waste/1031954/?

http://www.eaucwasteguide.org.uk/

Kaseva, M. E., & Mbuligwe, S. (2005). Appraisal of solid waste collection following private sector involvement in Dar es Salaam. Habitat International, 29, 353 – 366.

Kanakaraj, J., Velappan, K.C., Chandra Babu N.K. and Sadulla S. 2006 Solid wastes generation in the leather industry and its utilization for cleaner environment – A review. Journal of Scientific and Industrial research, UK, Vol. 65, pp. 541-548.

Larson, A. M., & Soto, F. (2008). Decentralisation of natural resources governance regimes. Annual Review of Environment and Resources, 33, 213 – 239.

Manga, V. E., Forton, O. T., & Read, A. (2008). Waste management in Cameroon: a new policy perspective? Resources, Conservation and Recycling, 52, 592 – 600.

Mbeng, L. O., Phillips, P. S, & Fairweather, R. (2009). Developing sustainable waste management practice: application of q methodology to construct new strategy component in Limbe e Cameroon. The Open Waste Management Journal, 2, 27 – 36.

Ministry of Trade, Industry and Cooperatives, MTIC, (2015). Uganda Micro, Small and Medium Enterprise (MSME) Policy: Sustainable MSMEs for Wealth Creation and Socio-Economic Transformation.

Rein Munter (2008). Industrial Wastewater Treatment, Ascondiv, Uk. 195 – 210

Sharma, P., Dhanwantri K. and Mehta, S. 2014. Solid Waste Management, Vol. 4, No. 1, pp. 49-54.

Subha G. K. (2013). Increasing Incidences of Water Pollution Imposing Hazardous Influence on Aquatic Fauna and Flora: A Grievous Environmental Concern, The Science Observer, UK, Vol.1, pp. 7.

United Nation Environmental Programme, UNEP, (1982). Environmental Quality Management for Selected Small and Medium scale Industries in Urban Areas: Assessment, Problems and Recommendations.